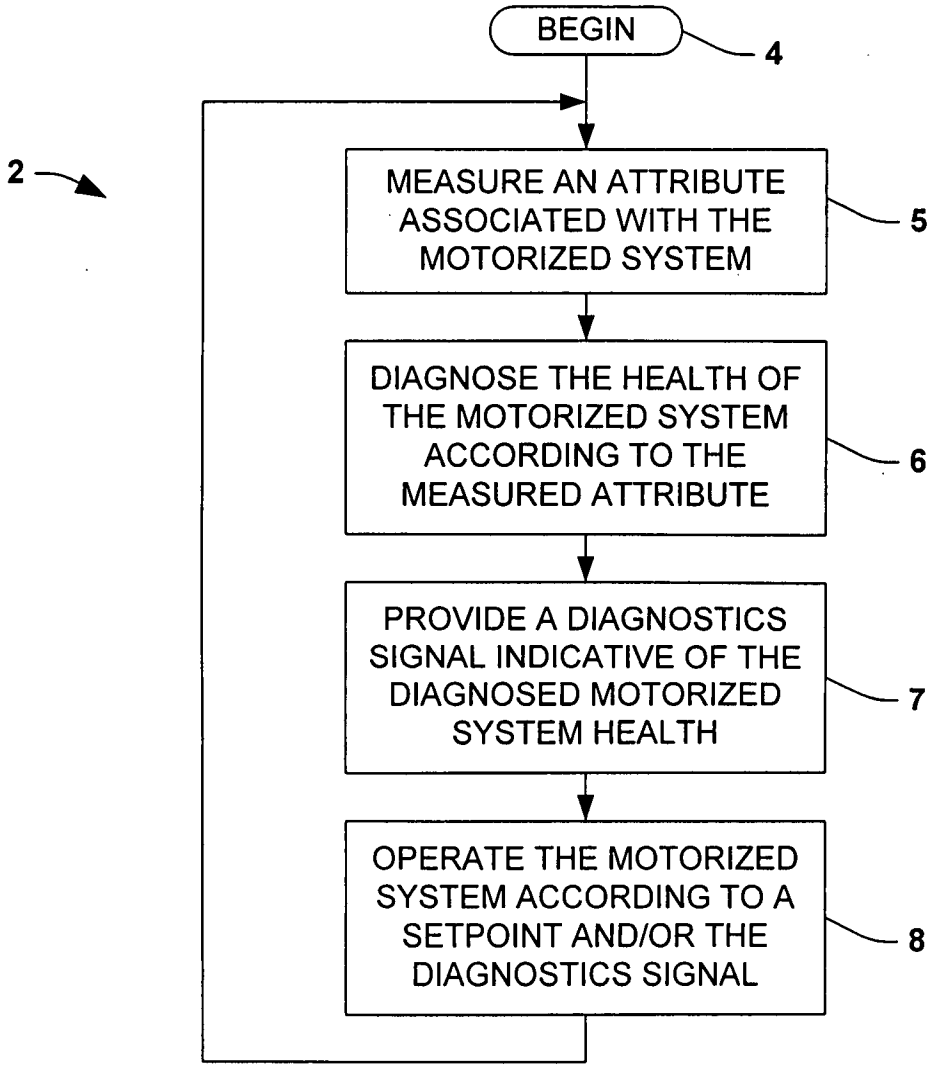

FIG. 1

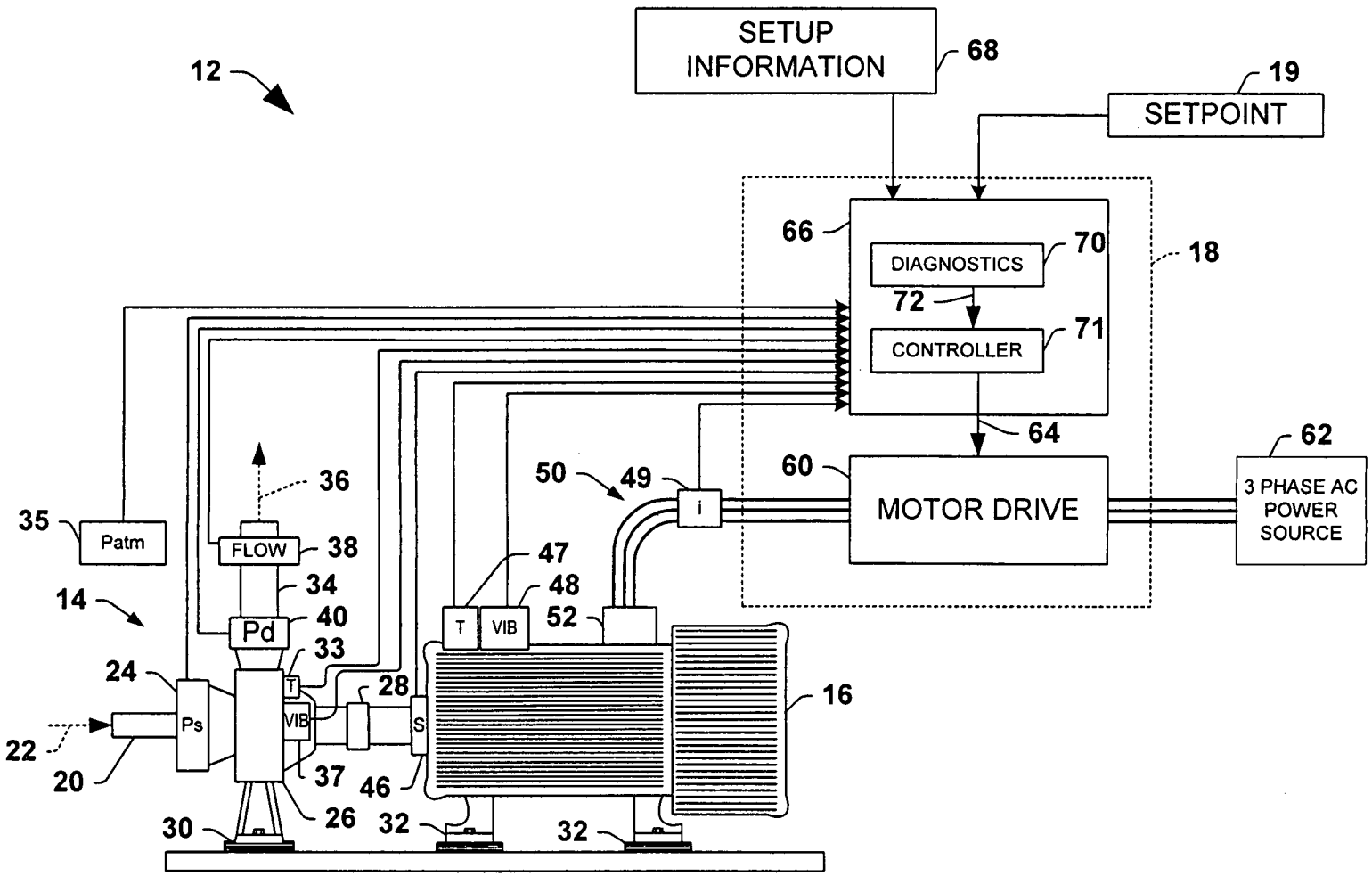

FIG. 2

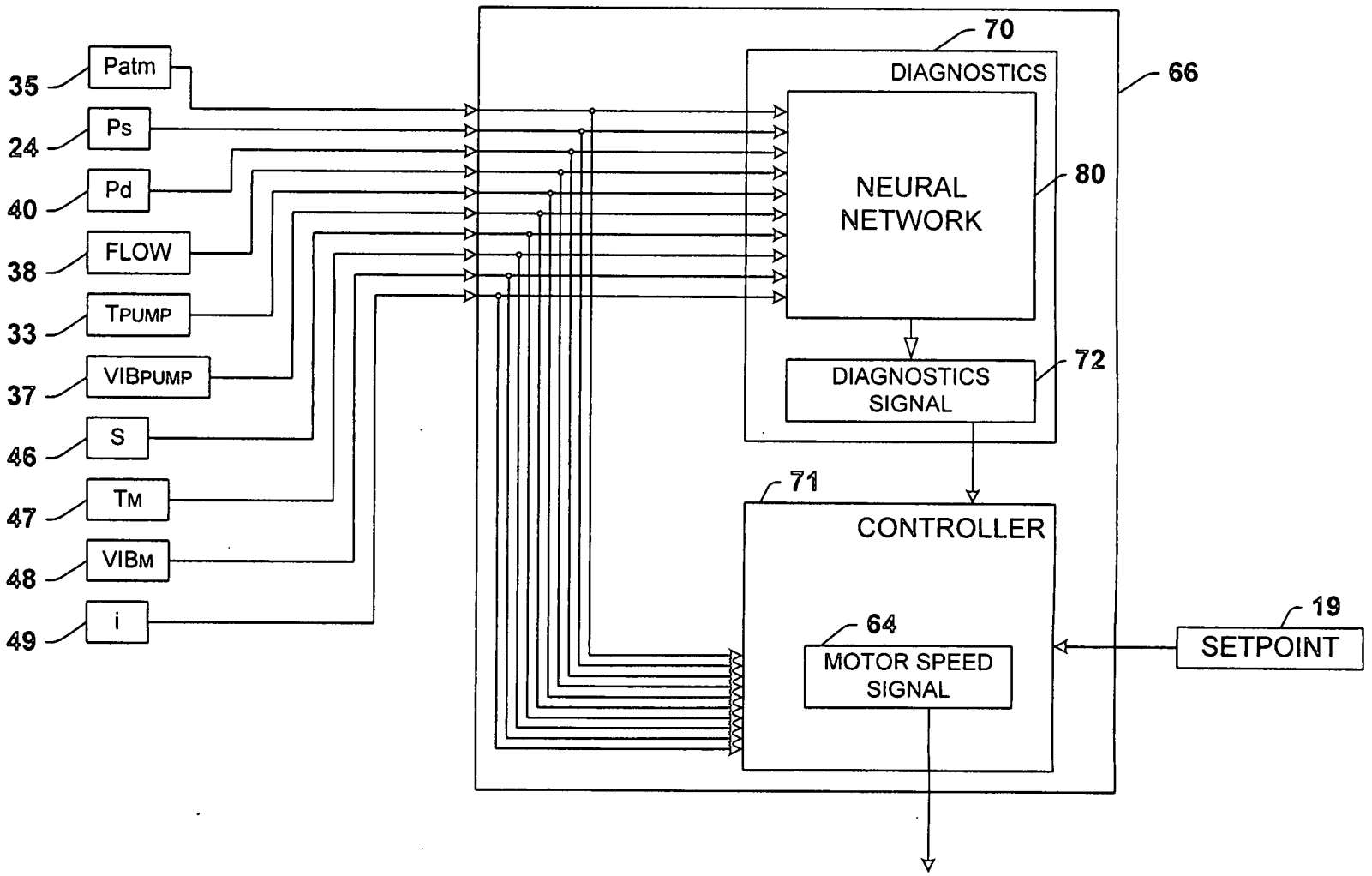

FIG. 3

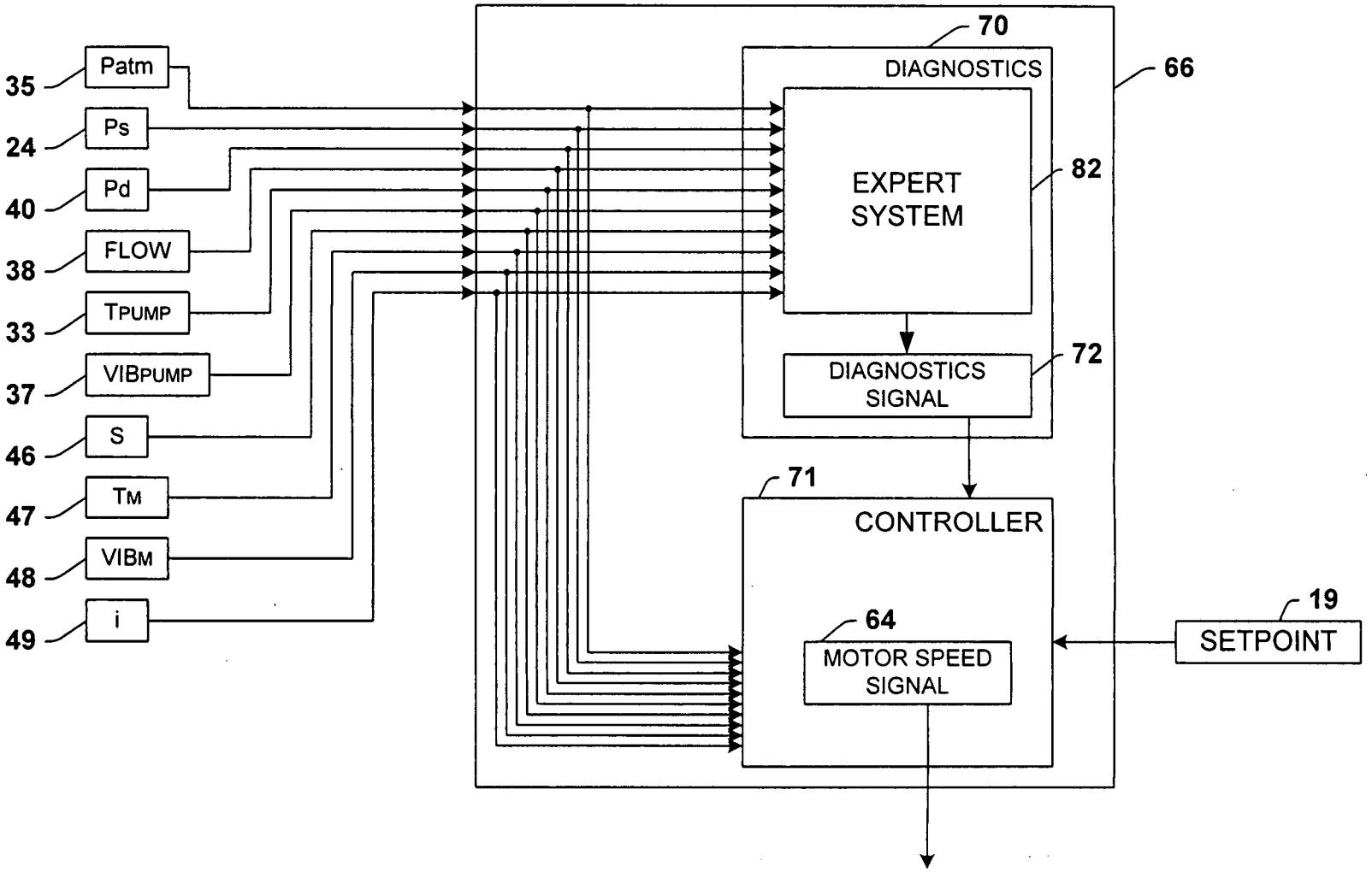

FIG. 4

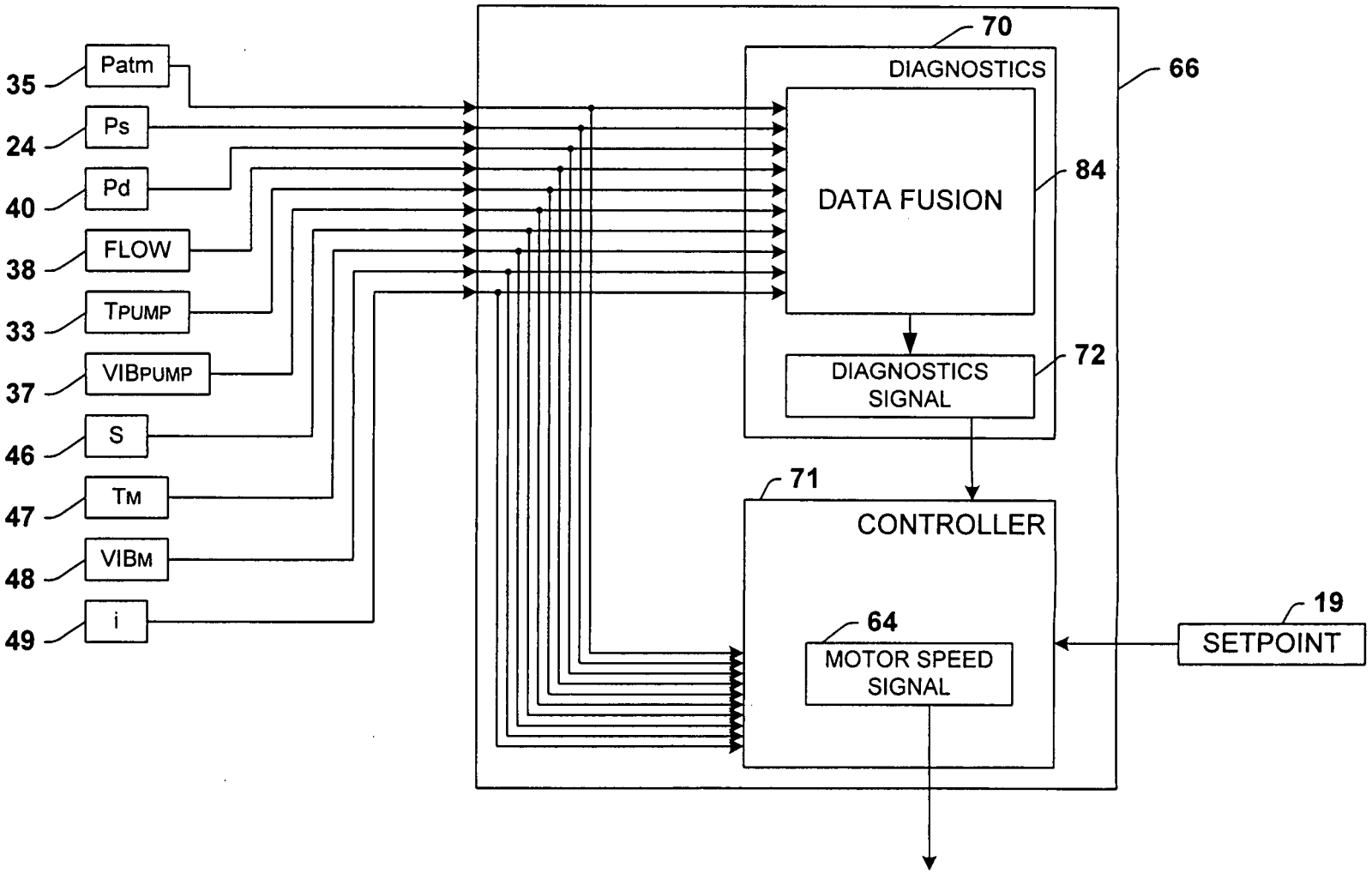

FIG. 5

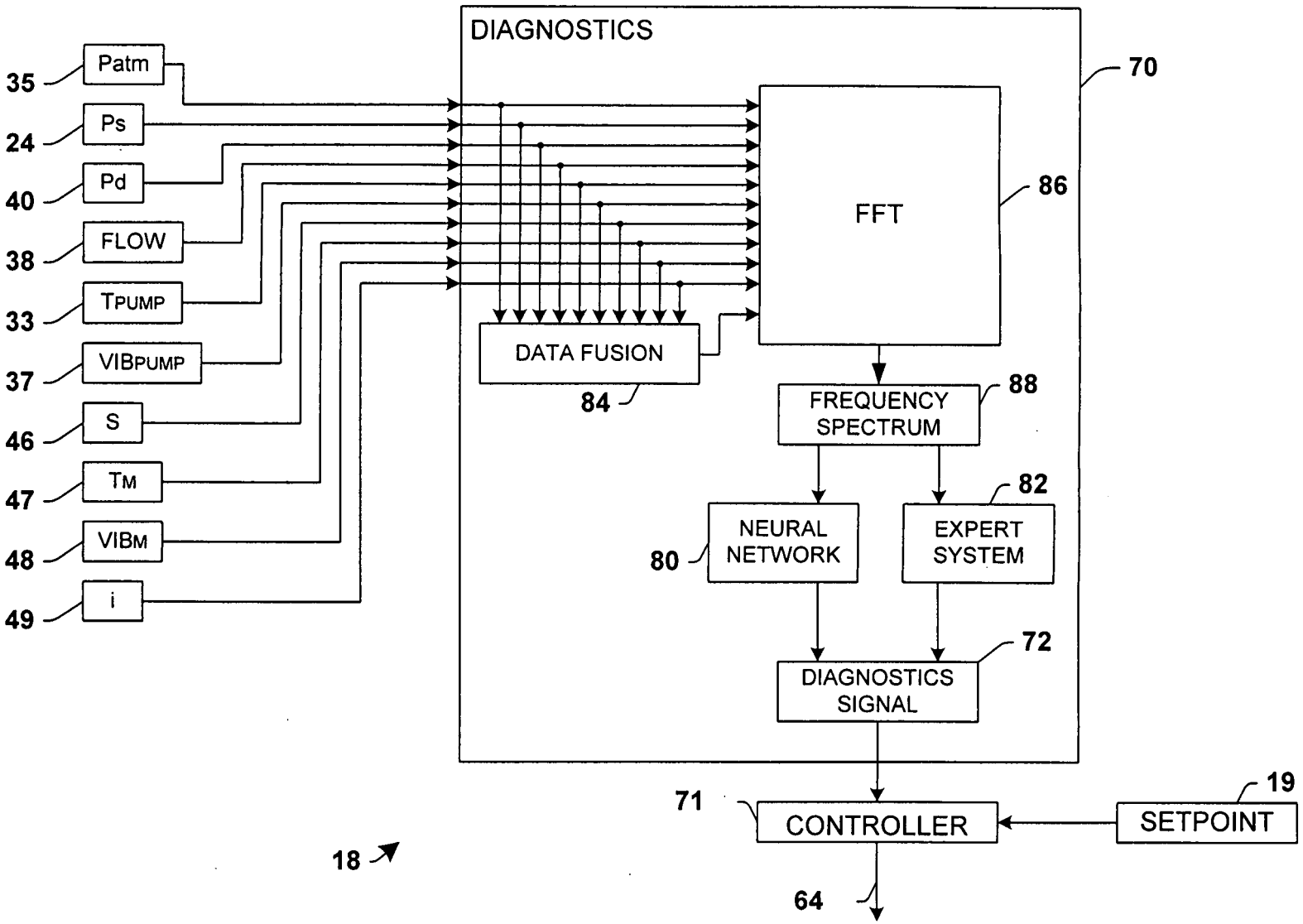

FIG. 6

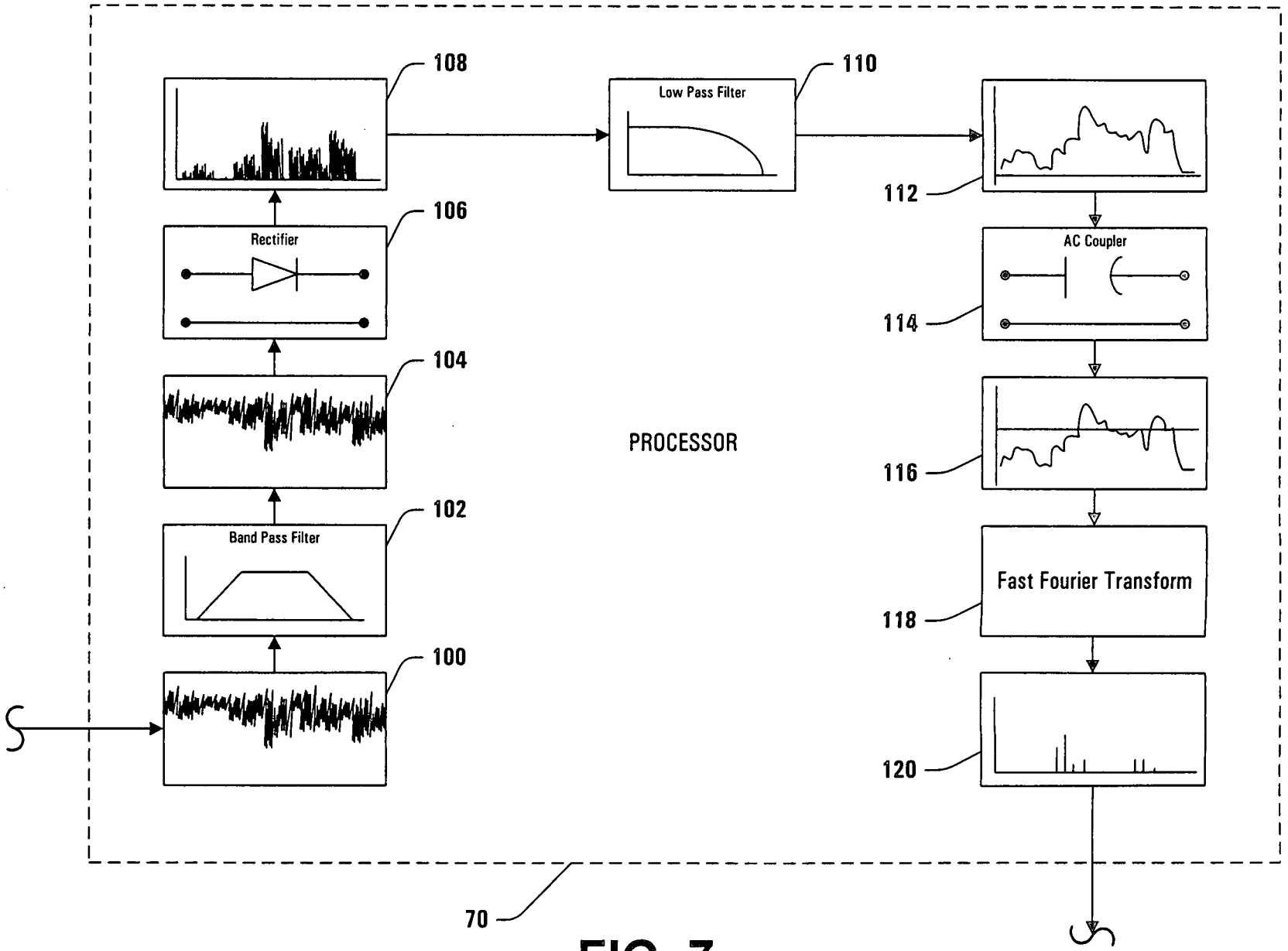

FIG. 7

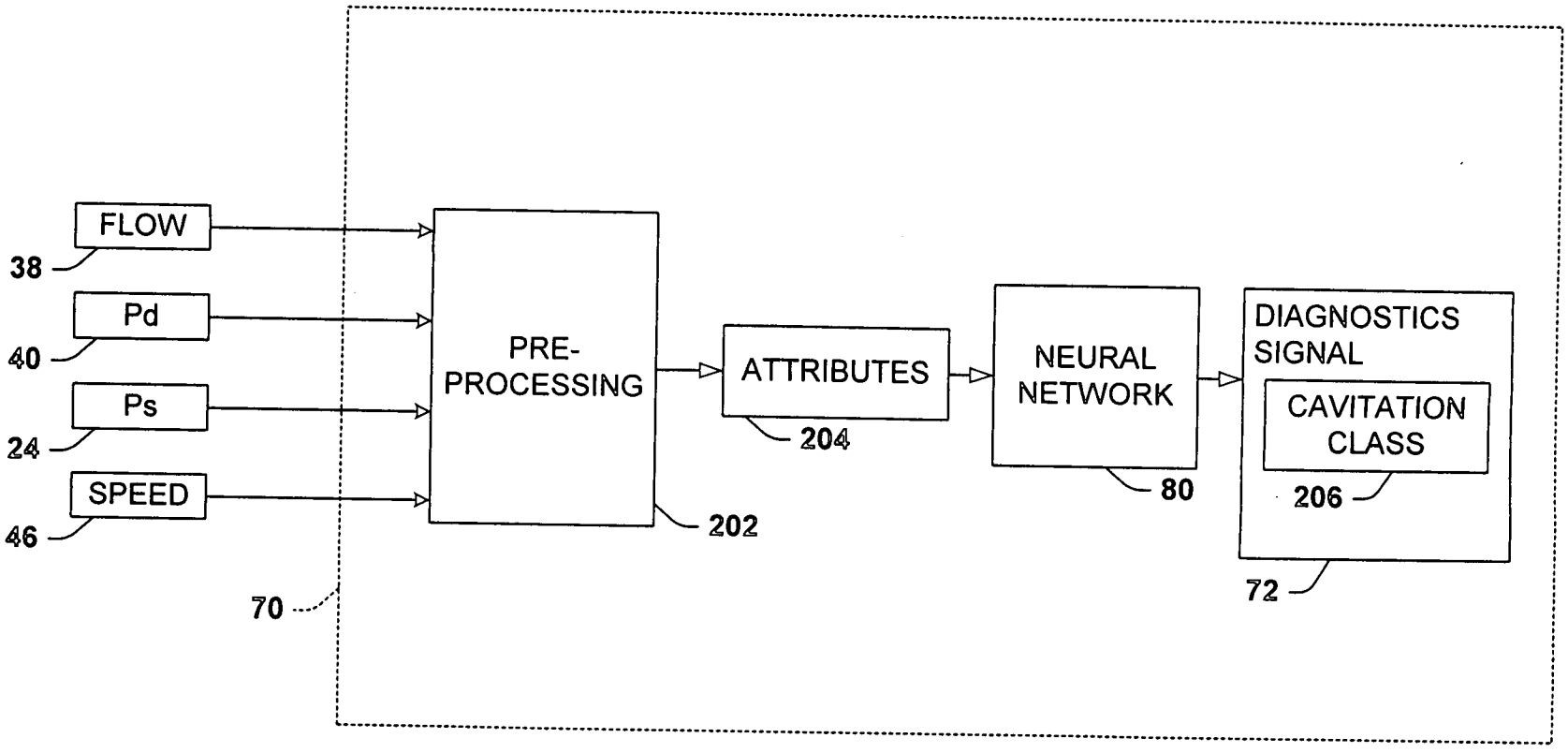

FIG. 8

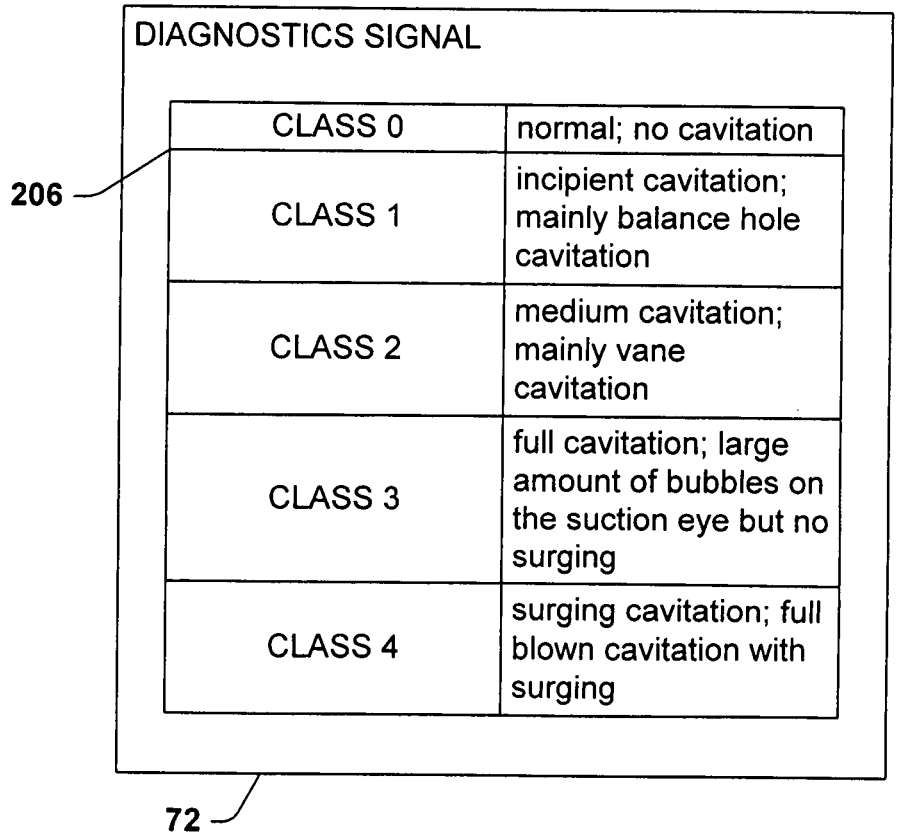

FIG. 9

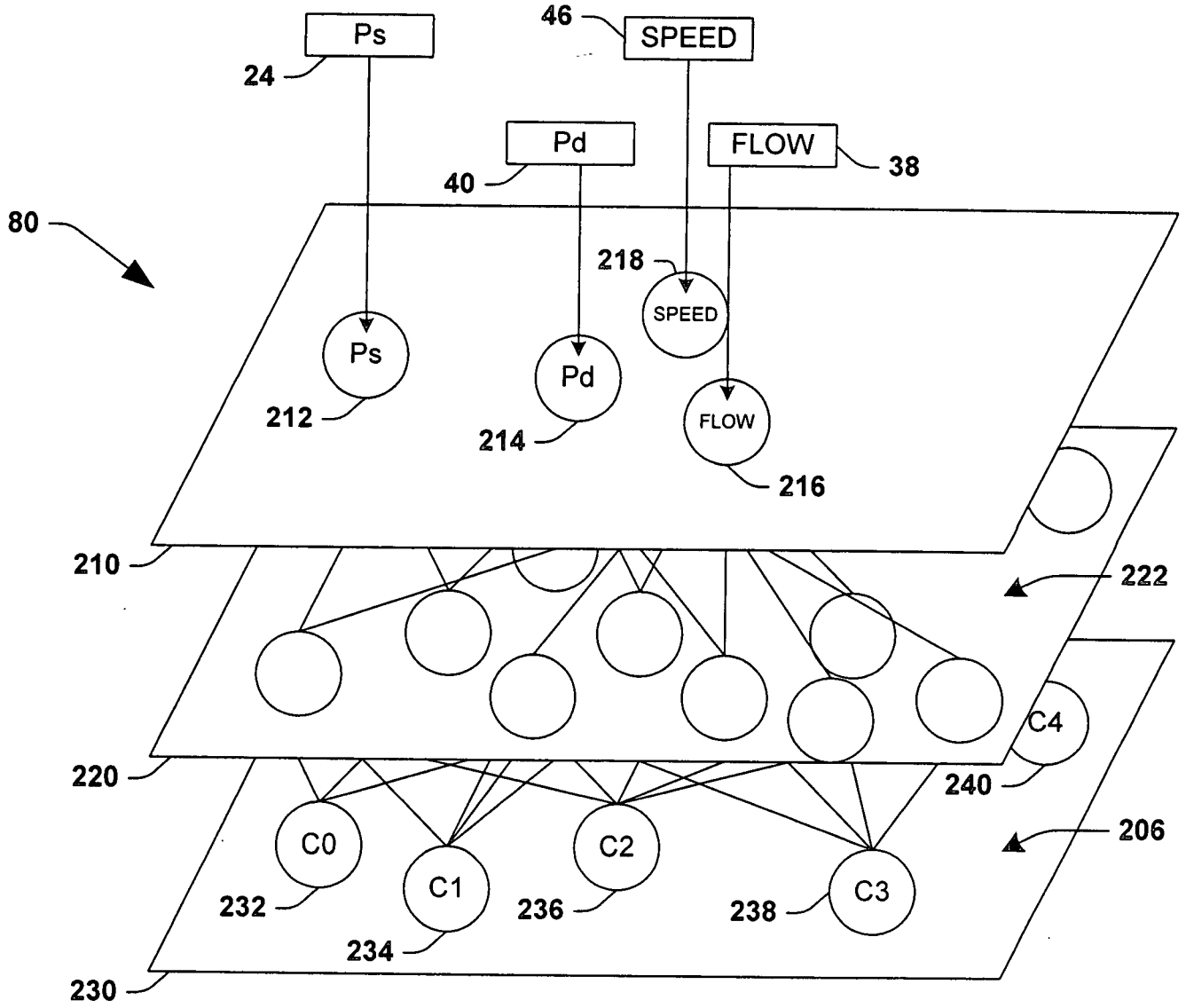
Ps
24
46
SPEED
Pd
40
FLOW
38
80
218
SPEED
Ps
212
Pd
214
FLOW
216
210
222
220
C4
240
206
C0
232
C1
234
C2
236
C3
238
230

FIG. 10

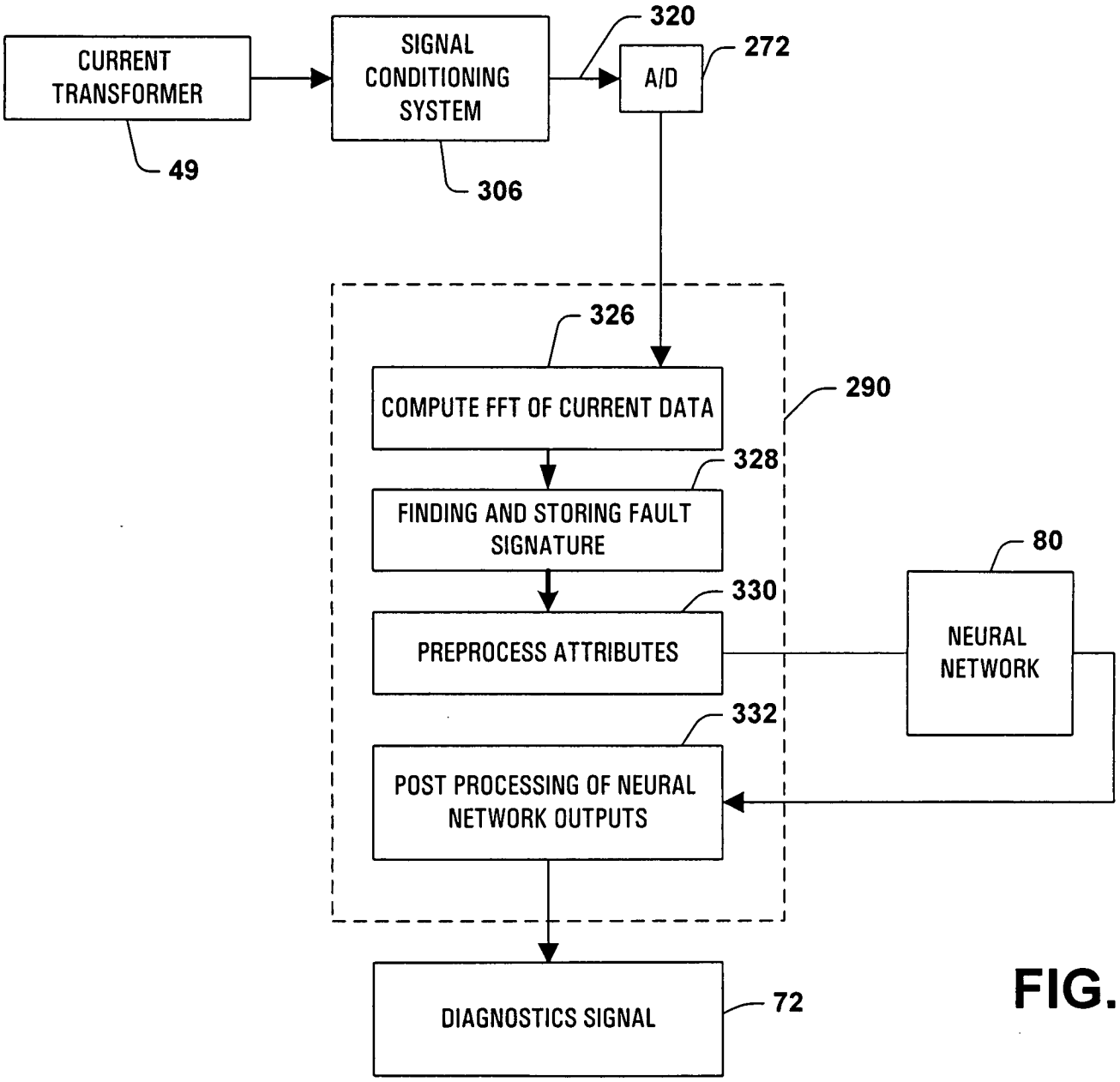

FIG. 11

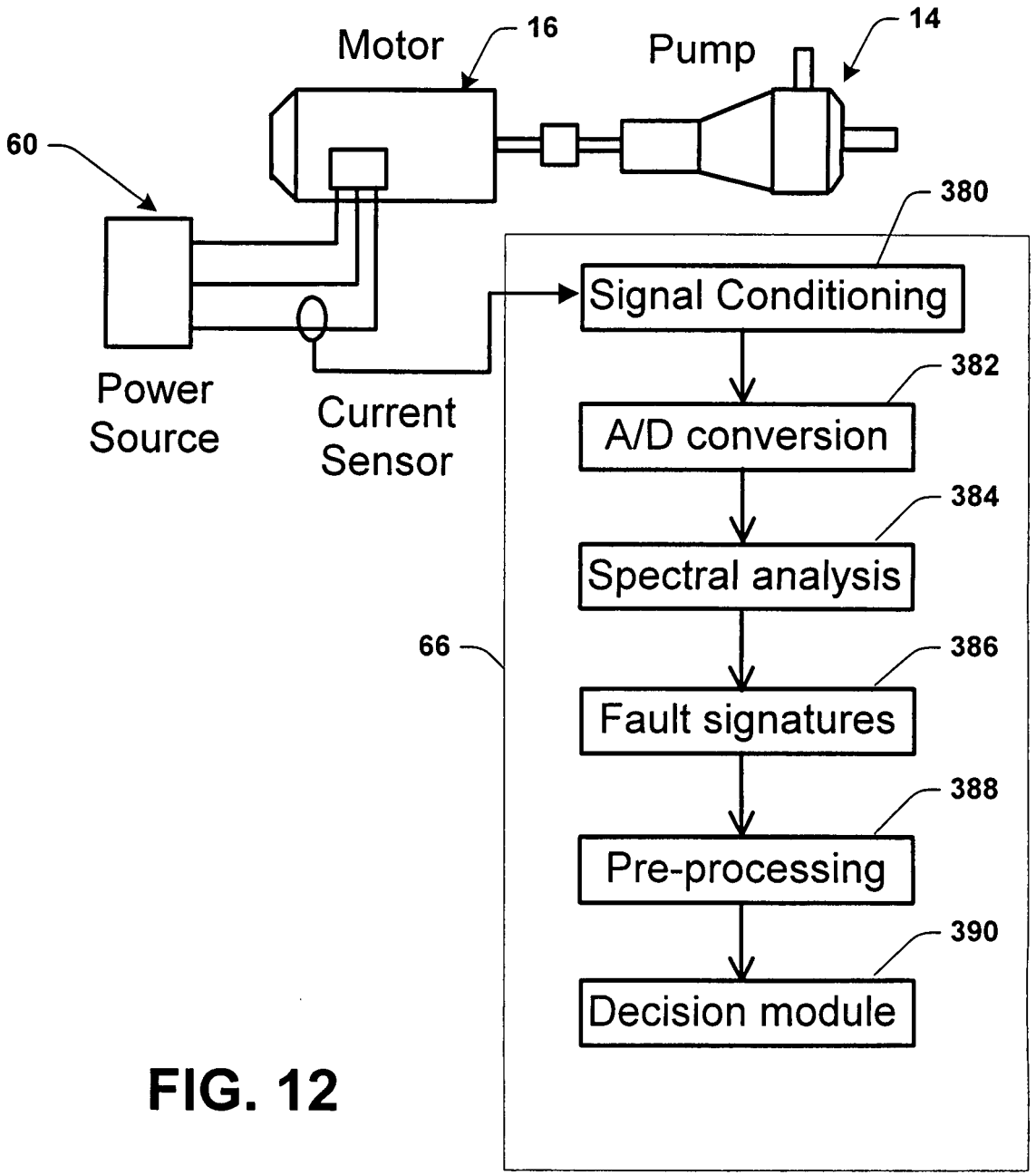

FIG. 12

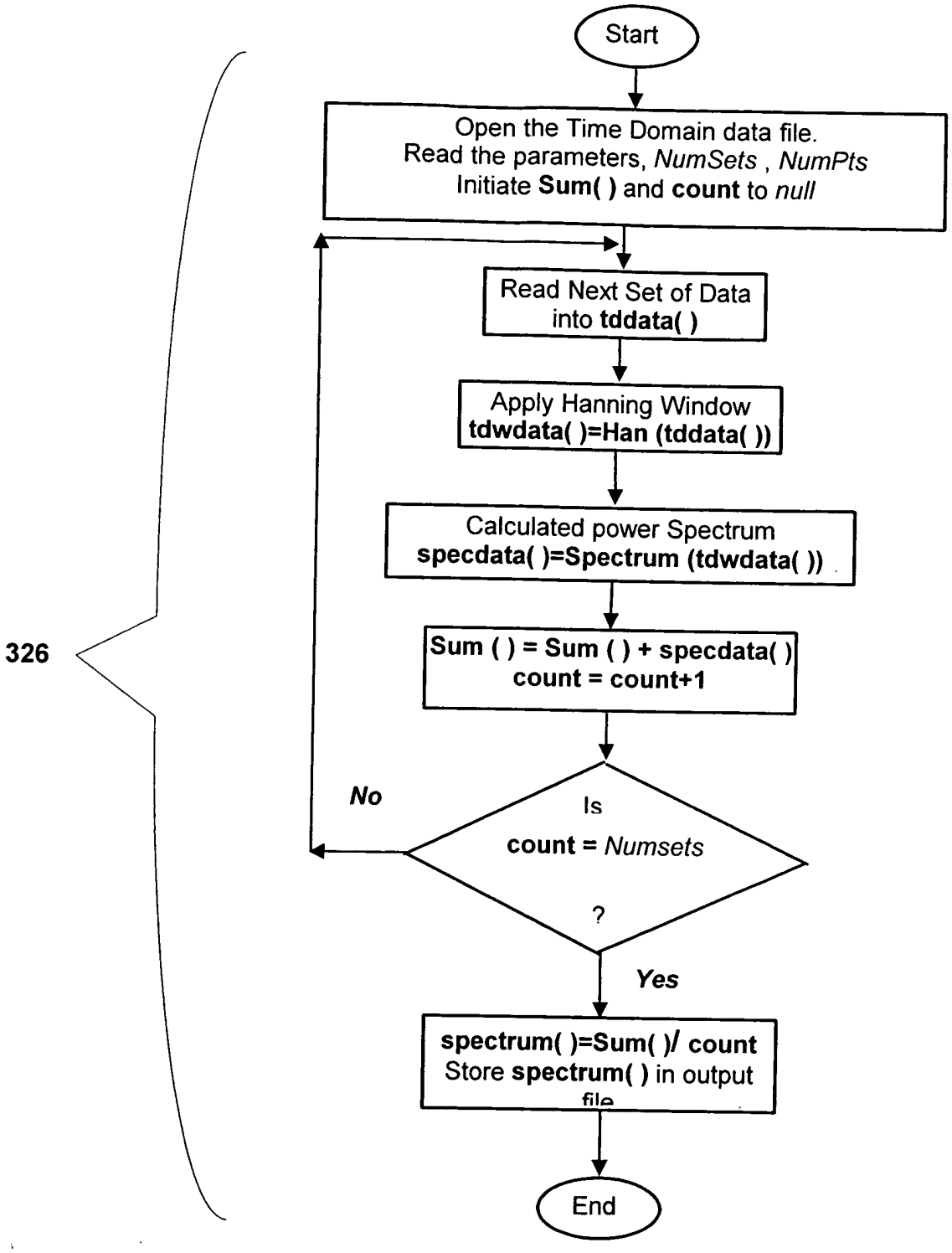
Start
Open the Time Domain data file.
Read the parameters, NumSets , NumPts
Initiate Sum( ) and count to null
Read Next Set of Data into tddata( )
Apply Hanning Window tdwdata( )=Han (tddata( ))
Calculated power Spectrum specdata( )=Spectrum (tdwdata( ))
Sum ( ) = Sum ( ) + specdata( )
count = count+1
No
Is count = Numsets ?
Yes
spectrum( )=Sum( )/ count
Store spectrum( ) in output file
End
326

FIG. 13

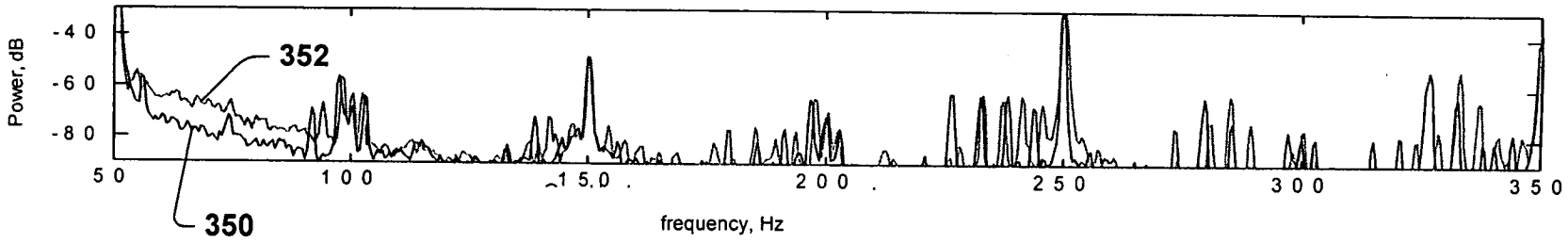

Fig. 14a

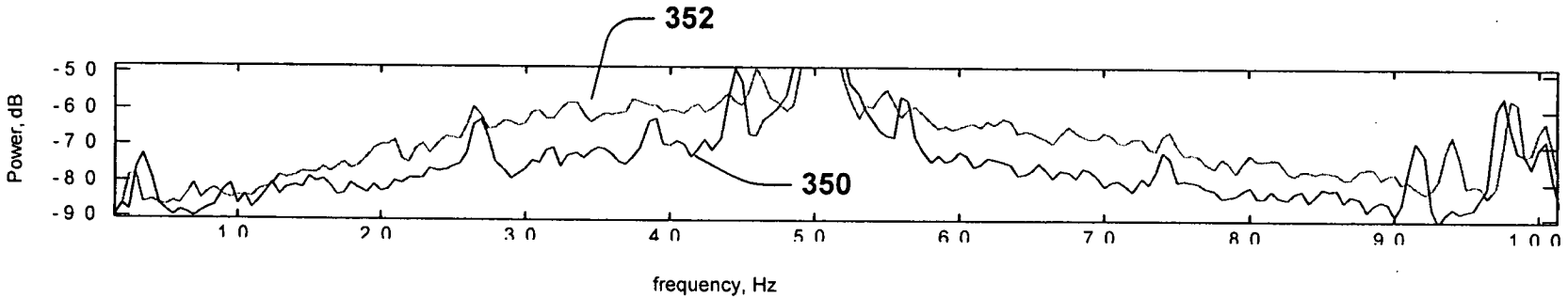

Fig. 14b

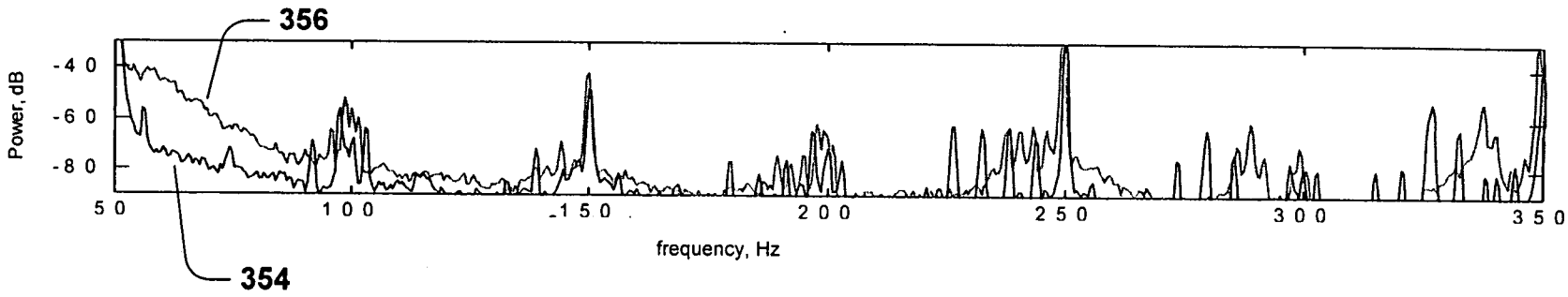

Fig. 14c

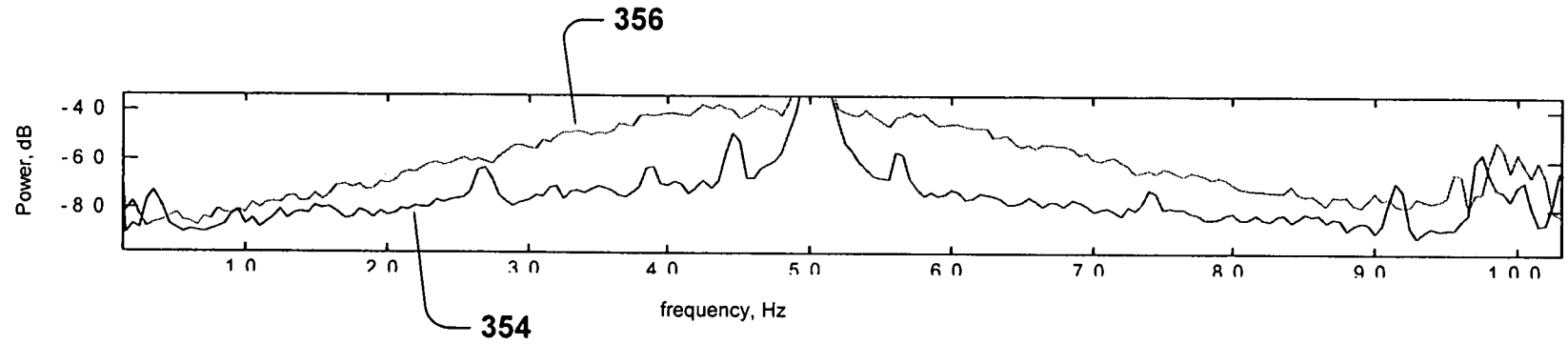

Fig. 14d

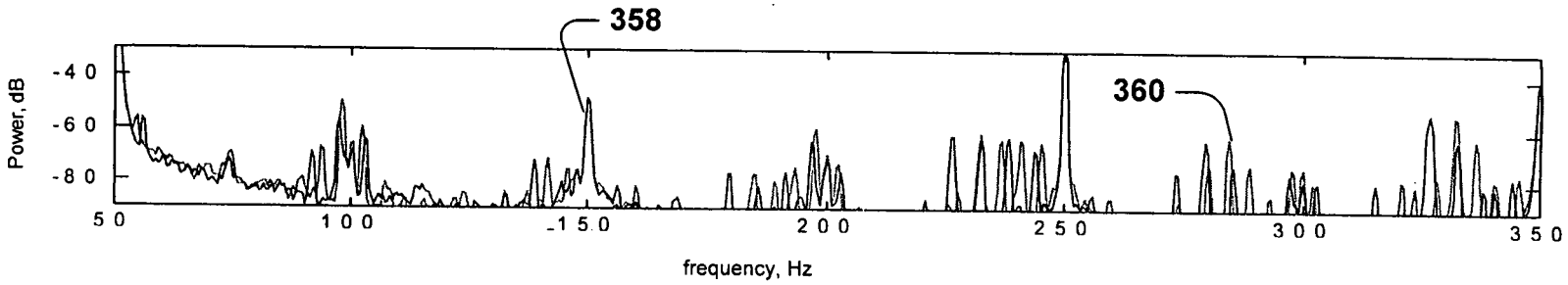

Fig. 14e

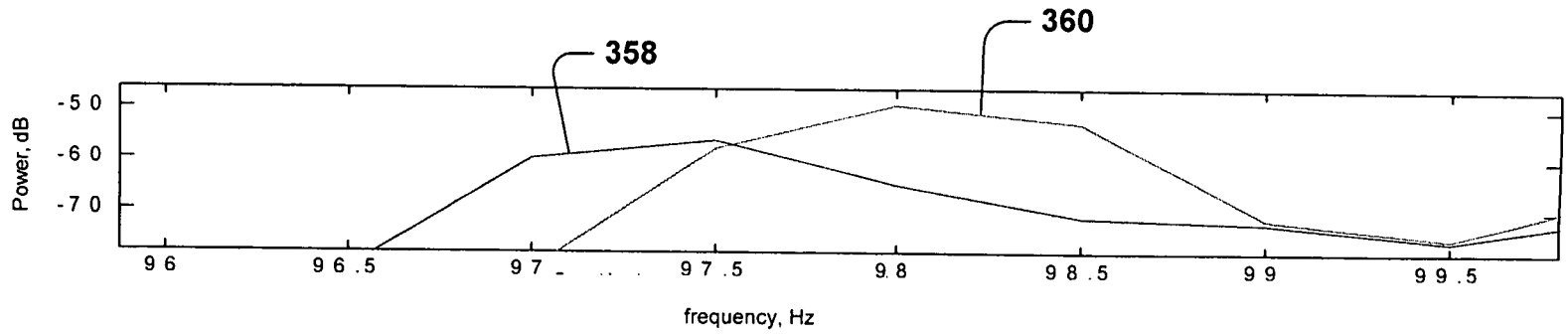

Fig. 14f

400

402

f_0	f_1	f_2	f_3	f_4	•	•	•	f_n	
A_3	A_{34}	A_{67}	A_{78}	A_{84}	•	•	•	A_K	HEALTHY PUMP
A_{34}	A_{-68}	A_{-90}	A_{-65}	A_{45}	•	•	•	A_H	PUMP FAULT 1
A_{56}	A_{45}	A_{45}	A_{56}	A_{78}	•	•	•	A_X	PUMP FAULT 2
A_{-23}	A_{45}	A_7	A_{90}	A_{12}	•	•	•	A_Z	PUMP FAULT 3
A_{67}	A_{36}	A_3	A_{45}	A_{47}	•	•	•	A_X	PUMP FAULT 4
A_{78}	A_{67}	A_{12}	A_{67}	A_{37}	•	•	•	A_C	PUMP FAULT 5
A_{234}	A_{27}	A_{478}	A_{24}	A_{127}	•	•	•	A_Q	PUMP FAULT 6
A_{-98}	A_{78}	A_{26}	A_{12}	A_{128}	•	•	•	A_B	PUMP FAULT 7
A_{26}	A_{96}	A_{83}	A_{56}	A_{234}	•	•	•	A_M	PUMP FAULT 8
A_4	A_{32}	A_{187}	A_{56}	A_{34}	•	•	•	A_I	PUMP FAULT 9
A_0	A_{16}	A_{73}	A_{76}	A_{33}	•	•	•	A_E	PUMP FAULT N-1
A_{75}	A_{17}	A_{45}	A_{69}	A_{44}	•	•	•	A_Q	PUMP FAULT N

404

FIG. 14g

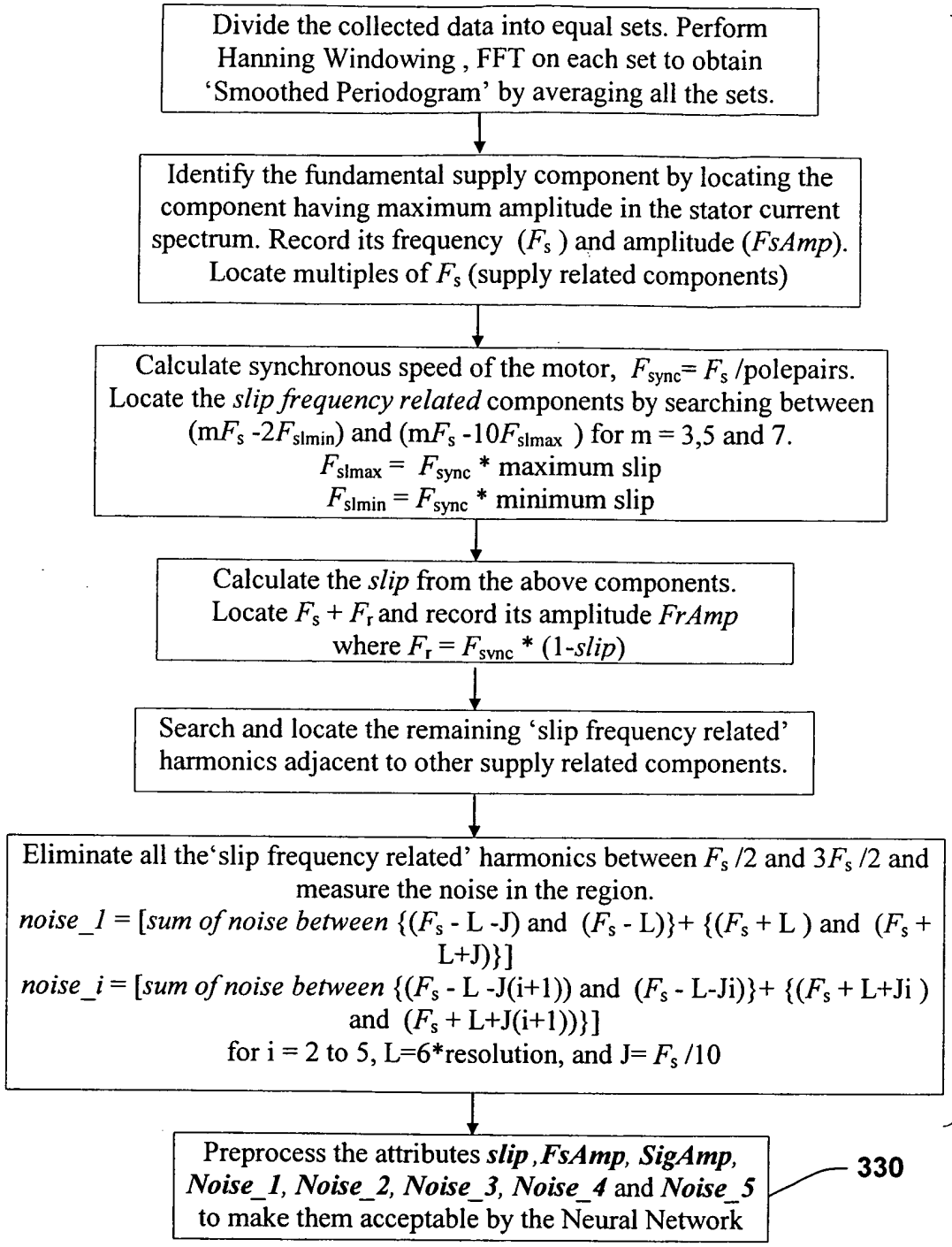
Divide the collected data into equal sets. Perform Hanning Windowing , FFT on each set to obtain 'Smoothed Periodogram' by averaging all the sets.
Identify the fundamental supply component by locating the component having maximum amplitude in the stator current spectrum. Record its frequency (F_s) and amplitude (*FsAmp*). Locate multiples of F_s (supply related components)
Calculate synchronous speed of the motor, $F_{sync} = F_s$ /polepairs. Locate the *slip frequency related* components by searching between ($mF_s - 2F_{slmin}$) and ($mF_s - 10F_{slmax}$) for m = 3,5 and 7.
$F_{slmax} = F_{sync}$ * maximum slip
$F_{slmin} = F_{sync}$ * minimum slip
Calculate the *slip* from the above components. Locate $F_s + F_r$ and record its amplitude *FrAmp* where $F_r = F_{svnc} * (1\text{-}slip)$
Search and locate the remaining 'slip frequency related' harmonics adjacent to other supply related components.
Eliminate all the'slip frequency related' harmonics between $F_s/2$ and $3F_s/2$ and measure the noise in the region.
noise_1 = [*sum of noise between* {(F_s - L -J) and (F_s - L)}+ {(F_s + L) and (F_s + L+J)}]
noise_i = [*sum of noise between* {(F_s - L -J(i+1)) and (F_s - L-Ji)}+ {(F_s + L+Ji) and (F_s + L+J(i+1))}]
for i = 2 to 5, L=6*resolution, and J= F_s /10
328
Preprocess the attributes ***slip***, ***FsAmp***, ***SigAmp***, ***Noise_1***, ***Noise_2***, ***Noise_3***, ***Noise_4*** and ***Noise_5*** to make them acceptable by the Neural Network
330

FIG. 15

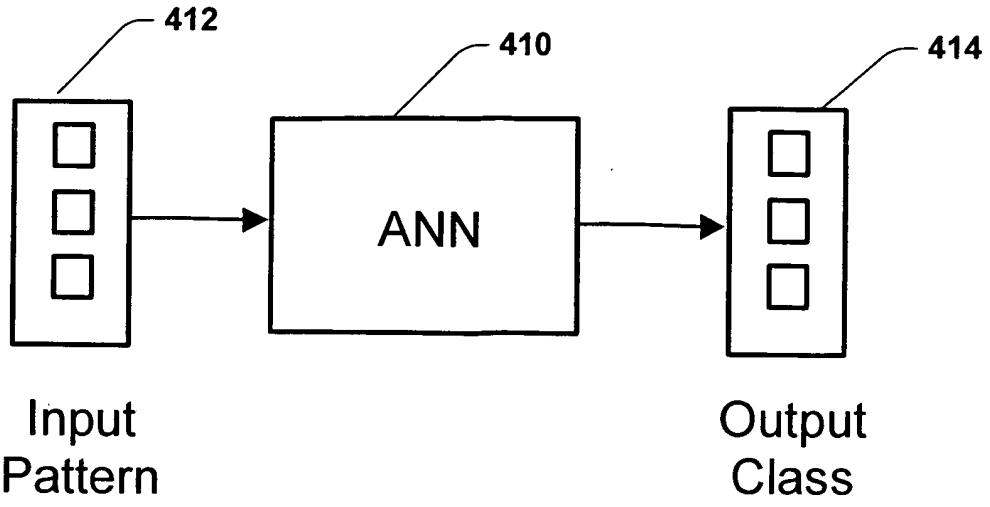
412
410
414
ANN
Input
Pattern
Output
Class

Fig. 16

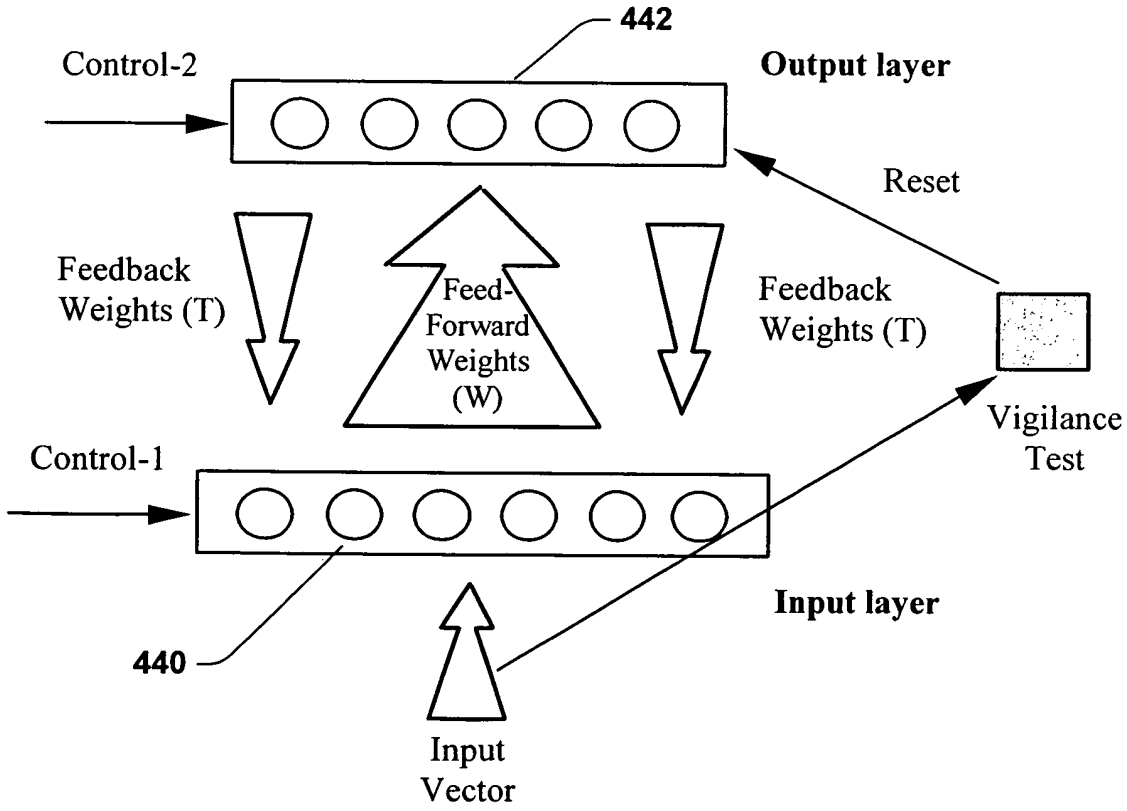
442
Control-2
Output layer
Reset
Feedback
Weights (T)
Feed-
Forward
Weights
(W)
Feedback
Weights (T)
Vigilance
Test
Control-1
Input layer
440
Input
Vector

Fig. 17

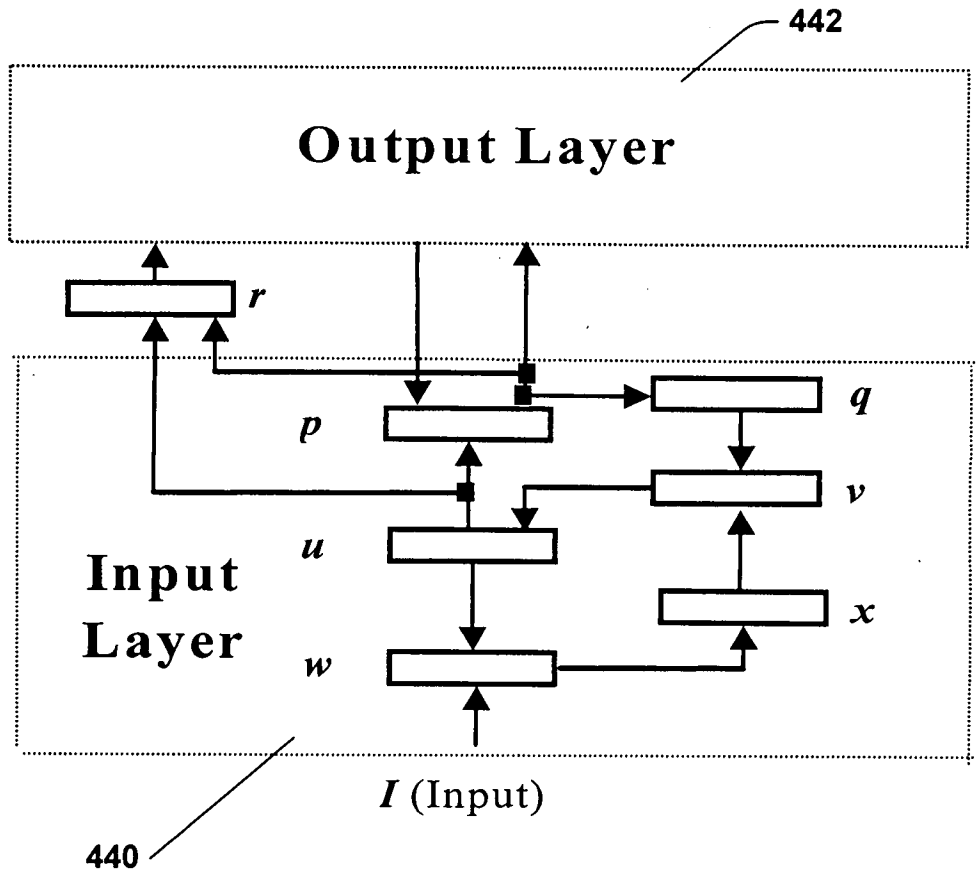

Fig. 18

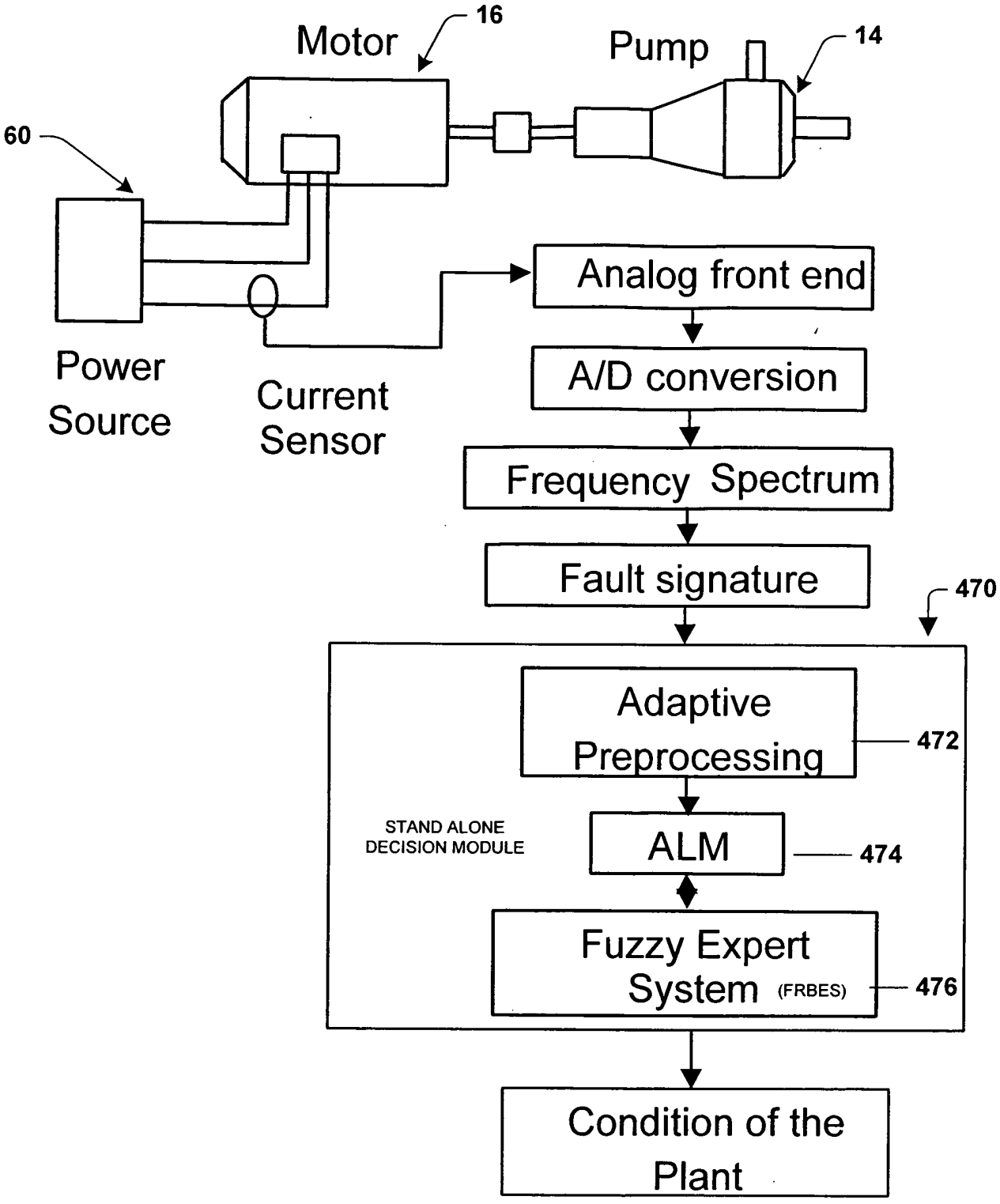

Fig. 19

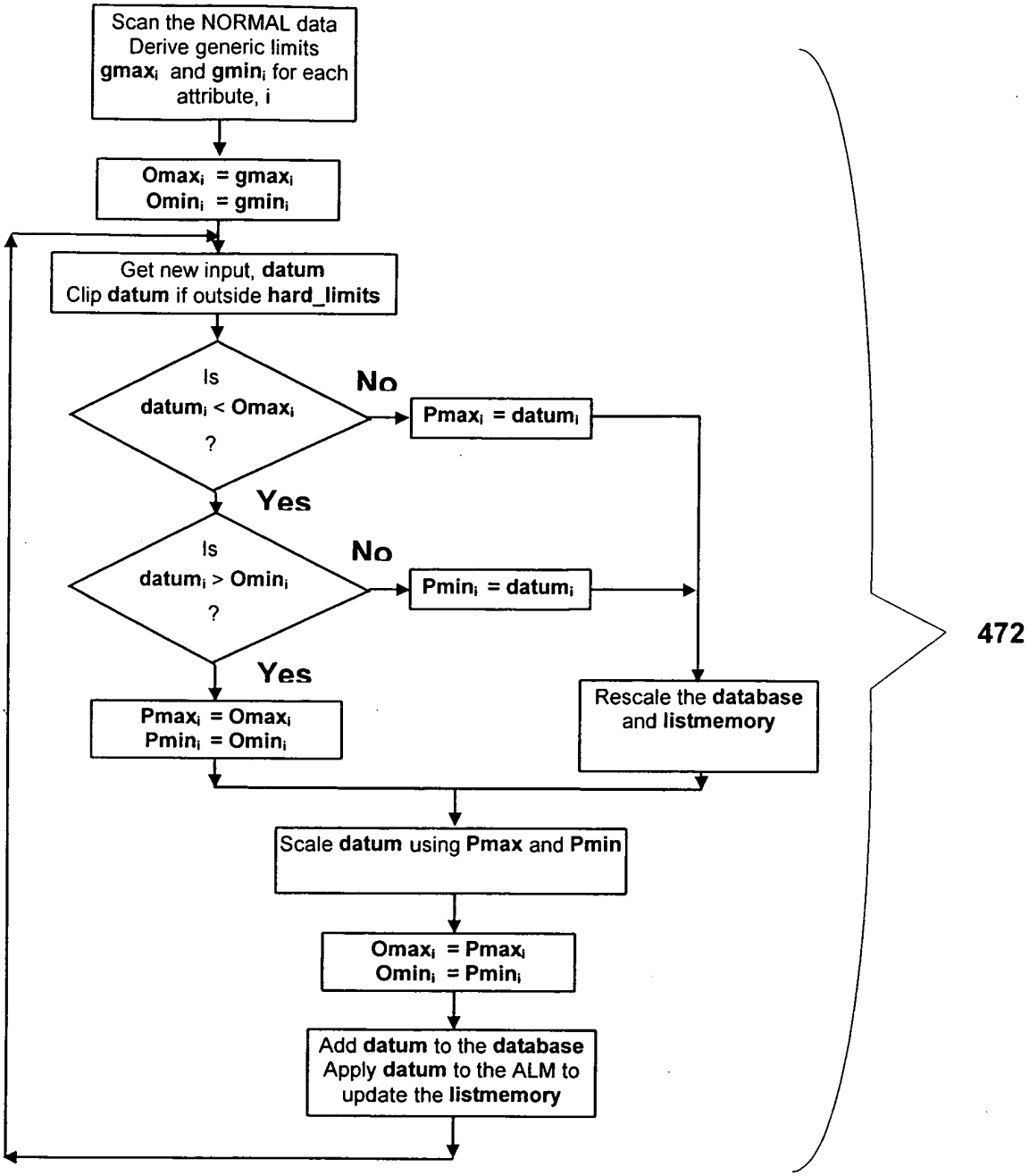
Scan the NORMAL data
Derive generic limits
gmax$_i$ and gmin$_i$ for each attribute, i
Omax$_i$ = gmax$_i$
Omin$_i$ = gmin$_i$
Get new input, datum
Clip datum if outside hard_limits
Is datum$_i$ < Omax$_i$?
No
Pmax$_i$ = datum$_i$
Yes
Is datum$_i$ > Omin$_i$?
No
Pmin$_i$ = datum$_i$
Yes
Pmax$_i$ = Omax$_i$
Pmin$_i$ = Omin$_i$
Rescale the database and listmemory
Scale datum using Pmax and Pmin
Omax$_i$ = Pmax$_i$
Omin$_i$ = Pmin$_i$
Add datum to the database
Apply datum to the ALM to update the listmemory
472

Fig. 20

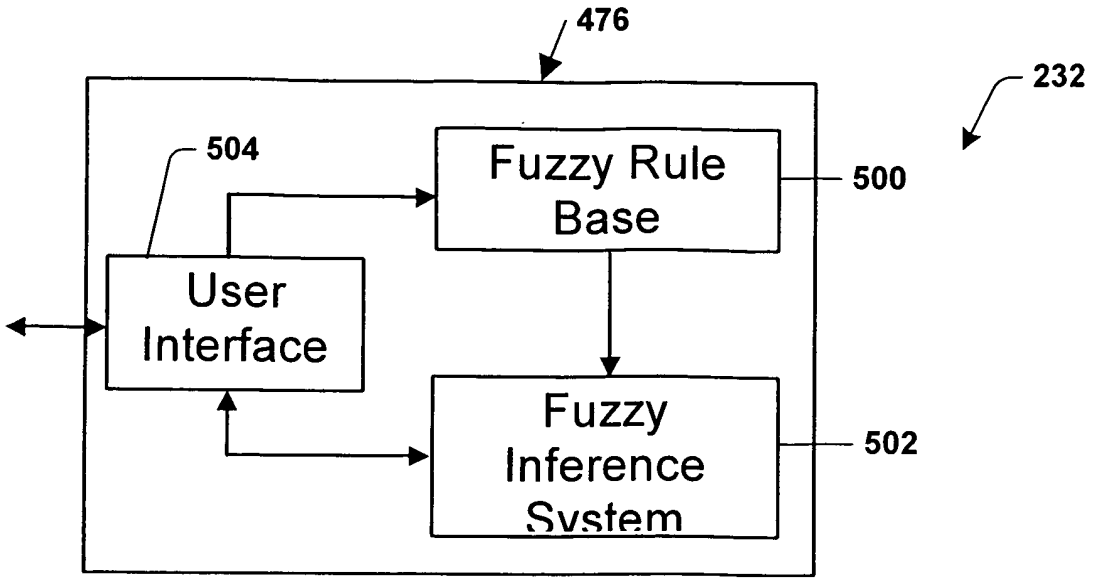
476
232
504
Fuzzy Rule Base
500
User Interface
Fuzzy Inference System
502

Fig. 21

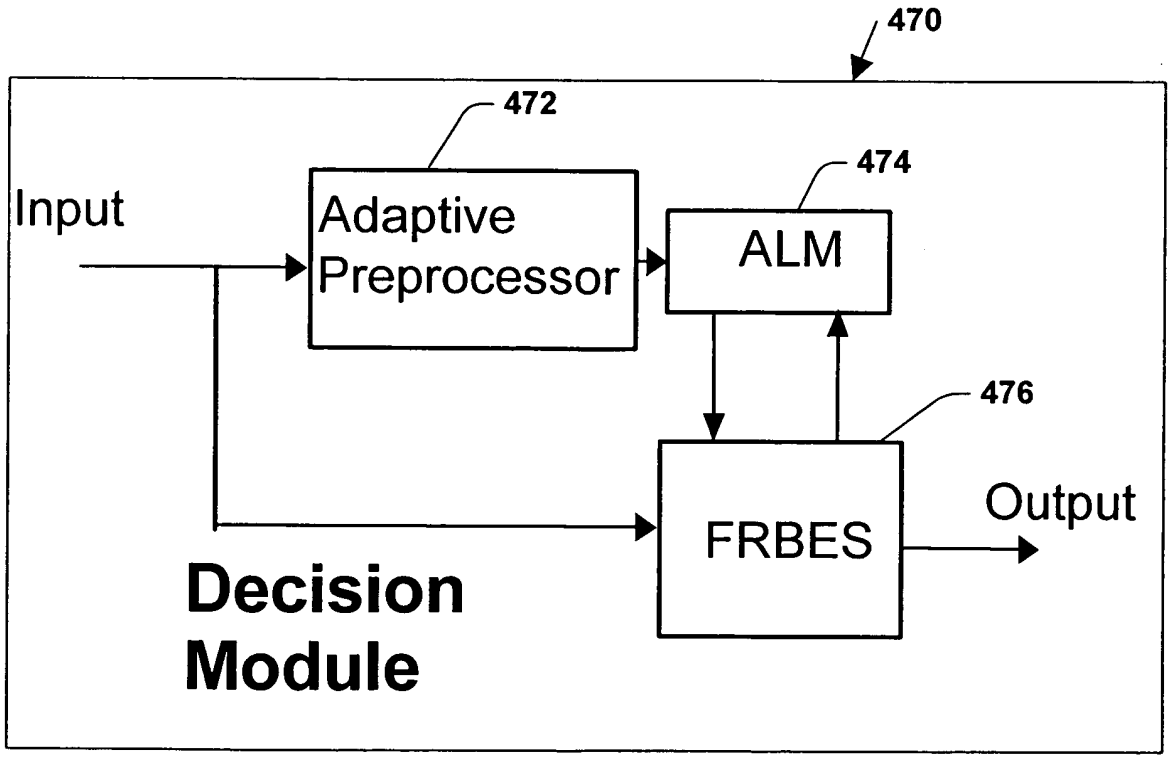
470
472
474
Input
Adaptive Preprocessor
ALM
476
FRBES
Output
Decision Module

Fig. 22

IF all the attributes are *NORMAL* **THEN** condition is normal
IF slip is *SLLO* and noise_2 is *HI* **THEN** condition is low-cav
IF noise_4 and noise_5 are *VERHI* **THEN** condition is sev-cav
IF noise_4 and noise_5 are *HI* **THEN** condition is sev-cav
IF FsAmp is *SLLO* and noise_5 are *SLHI* **THEN** condition is sev-cav
IF FsAmp is *LO* and noise_5 is *SLHI* **THEN** condition is sev-cav
IF FsAmp is *VERLO* and noise_5 is *SLHI* **THEN** condition is sev-cav
IF FsAmp is *SLLO* and noise_4 are *HI* **THEN** condition is sev-cav
IF FsAmp is *LO* and noise_4 is *HI* **THEN** condition is sev-cav
IF FsAmp is *LO* and noise_4 is *VERHI* **THEN** condition is sev-cav
IF FsAmp is *SLLO* and slip is *SLLO* and noise_4 is *NORMAL* and noise_5 is *NORMAL* **THEN** condition is low-block
IF FsAmp is *LO* and noise_4 is *NORMAL* and noise_5 is *NORMAL* **THEN** condition is sev-block
IF slip and FsAmp are *VERLO* **THEN** condition is sev-block
IF FrAmp is *HI* **THEN** condition is impel-fault
IF framp is *VERHI* **THEN** condition is impel-fault

Fig. 23

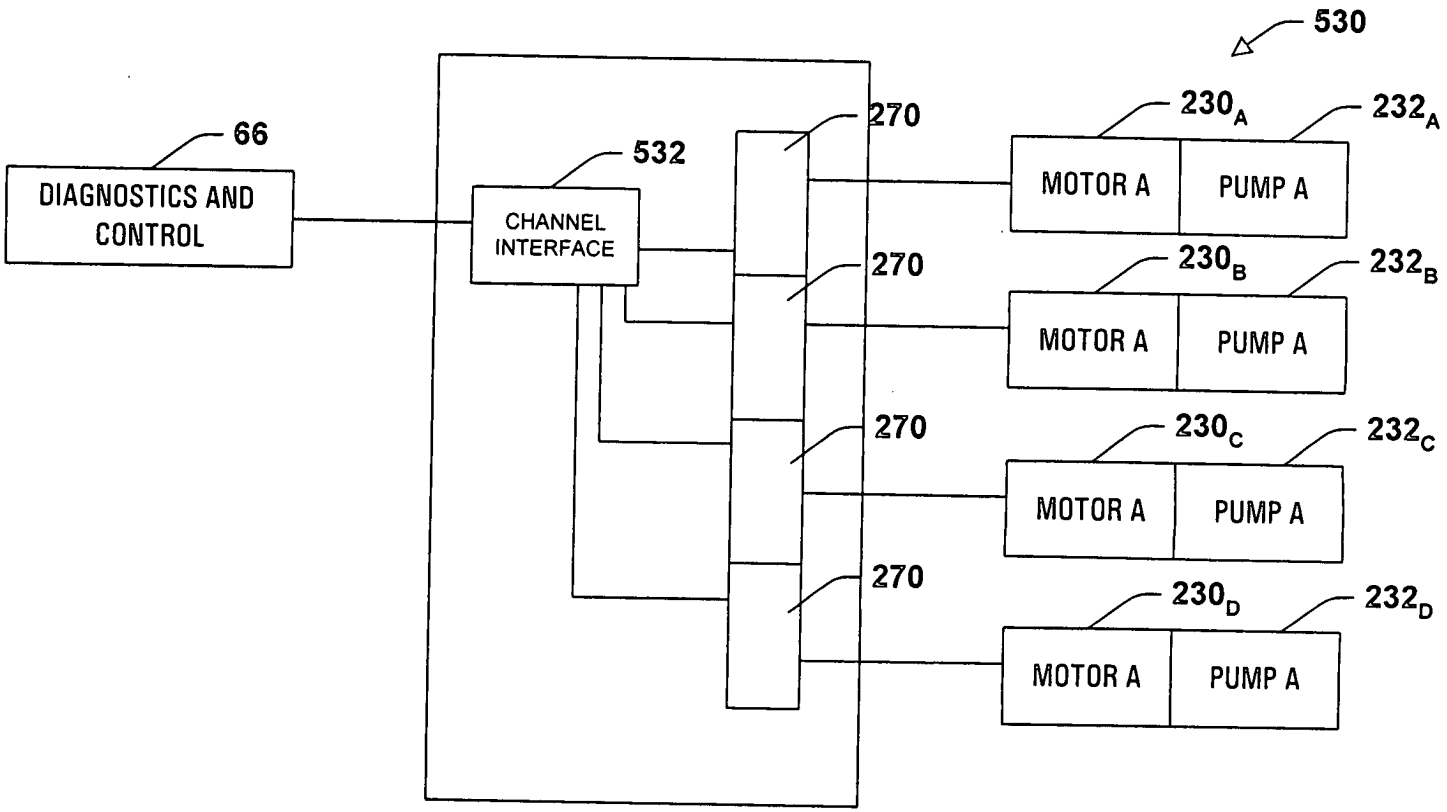

Fig. 24

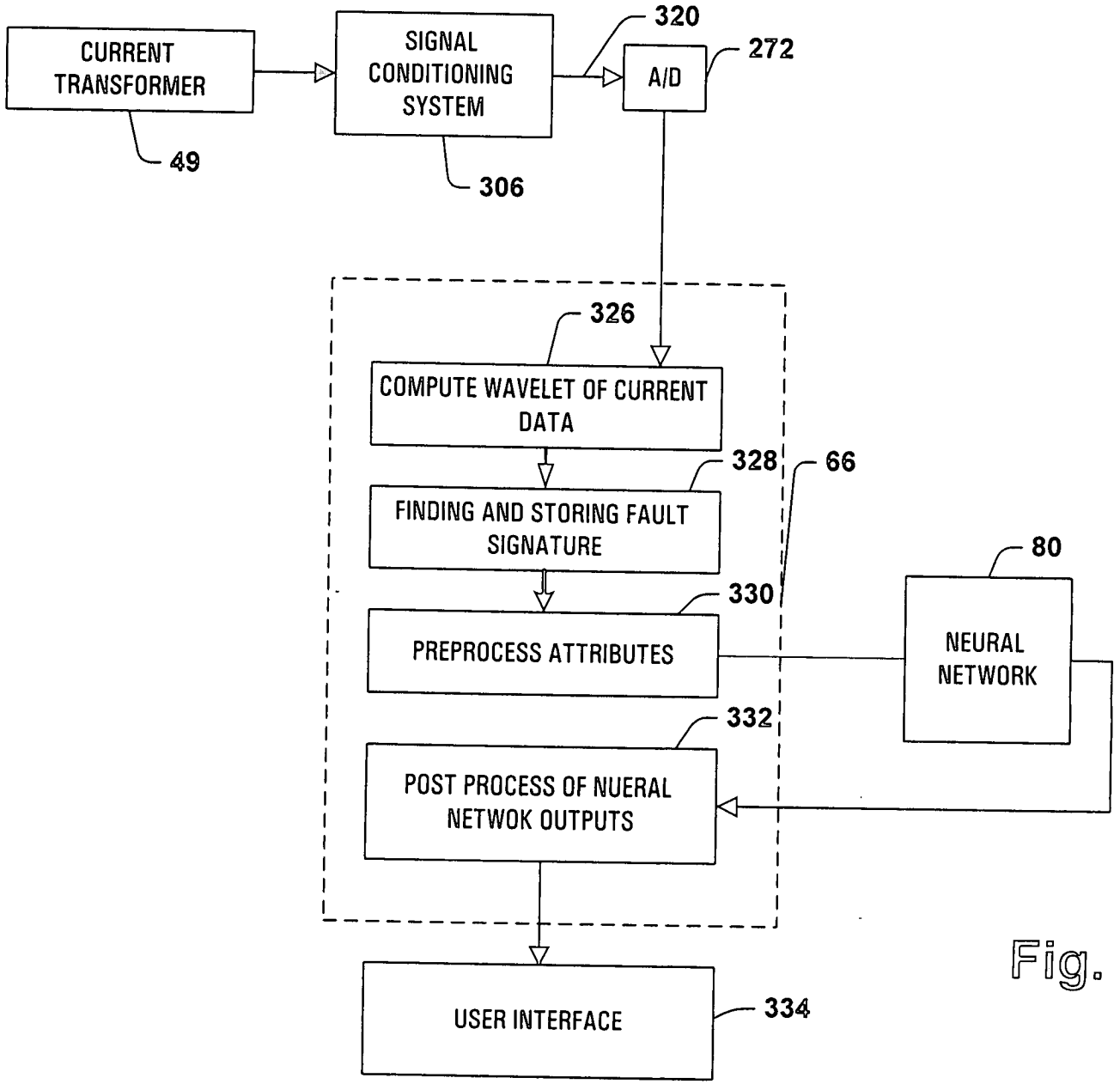

Fig. 25

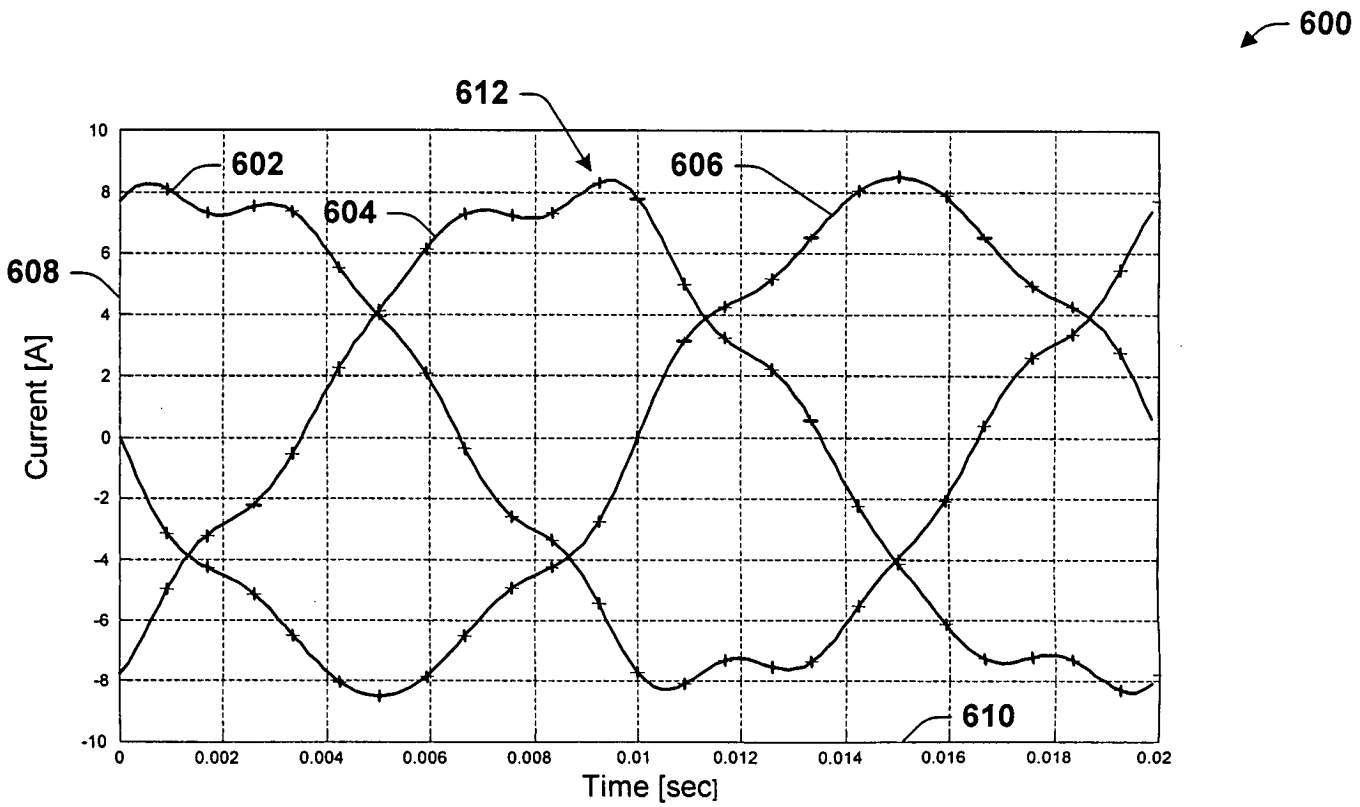
600
612
602
606
604
608
610
Current [A]
Time [sec]
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0.02

FIG. 26

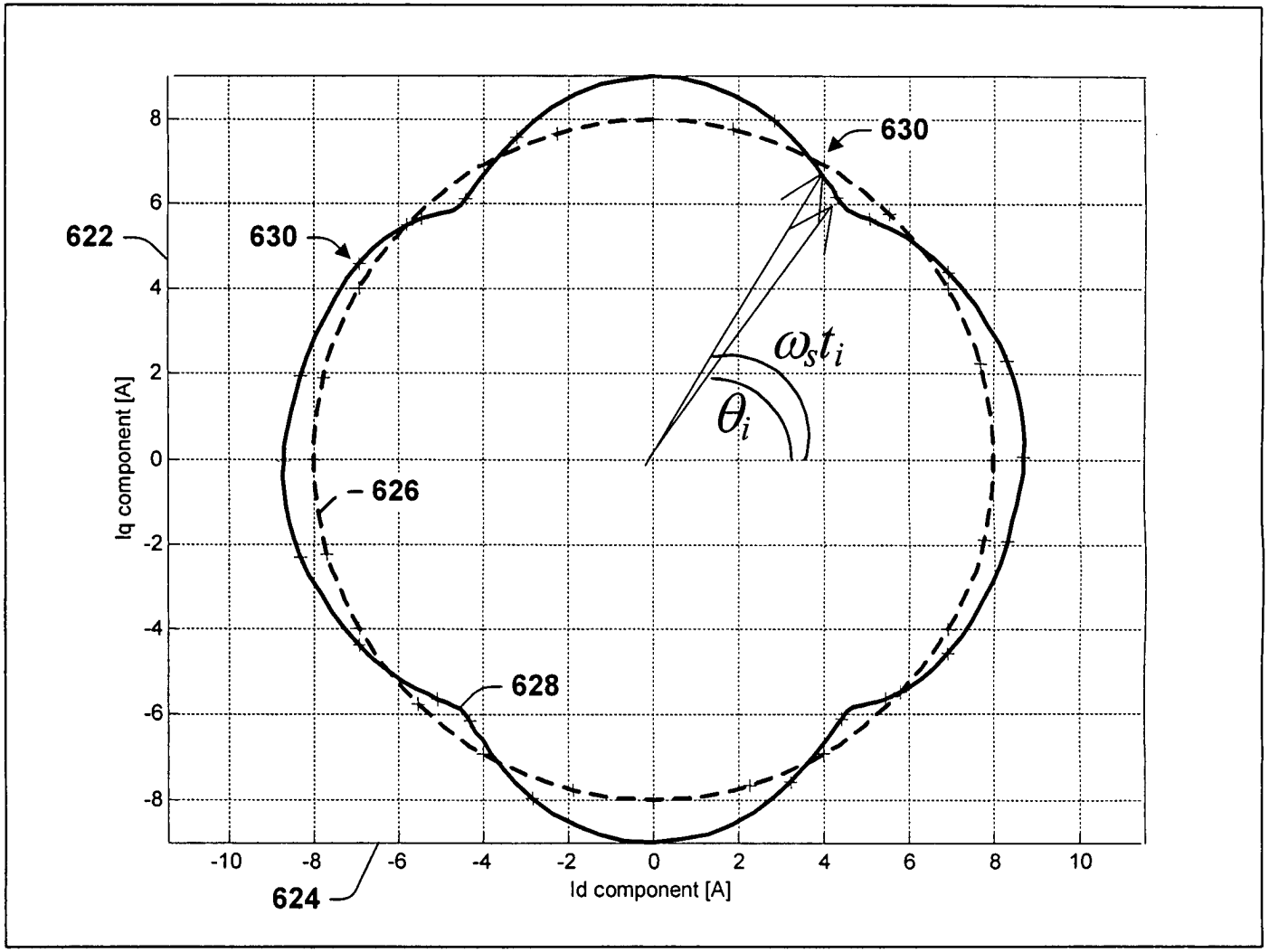
620
630
622
630
626
628
624
$\omega_s t_i$
θ_i
Iq component [A]
Id component [A]
8
6
4
2
0
-2
-4
-6
-8
-10
-8
-6
-4
-2
0
2
4
6
8
10

FIG. 27

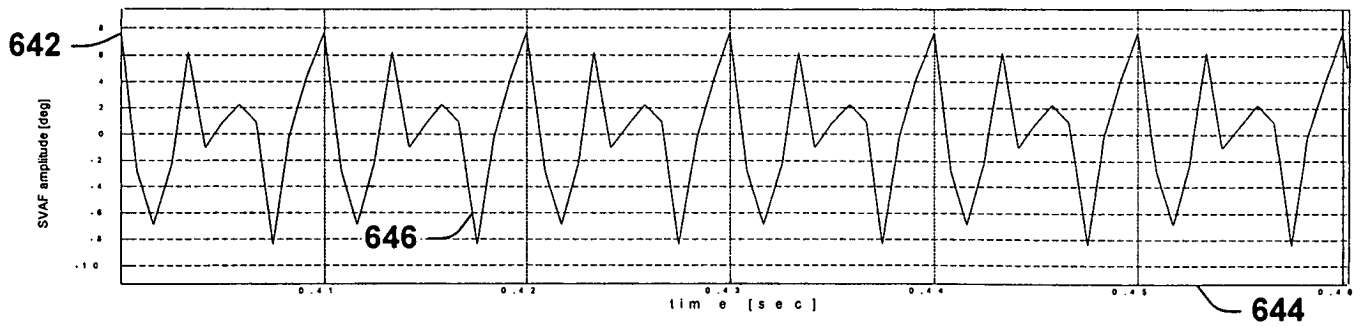
642
640
646
644
SVAF amplitude [deg]
time [sec]

FIG. 28

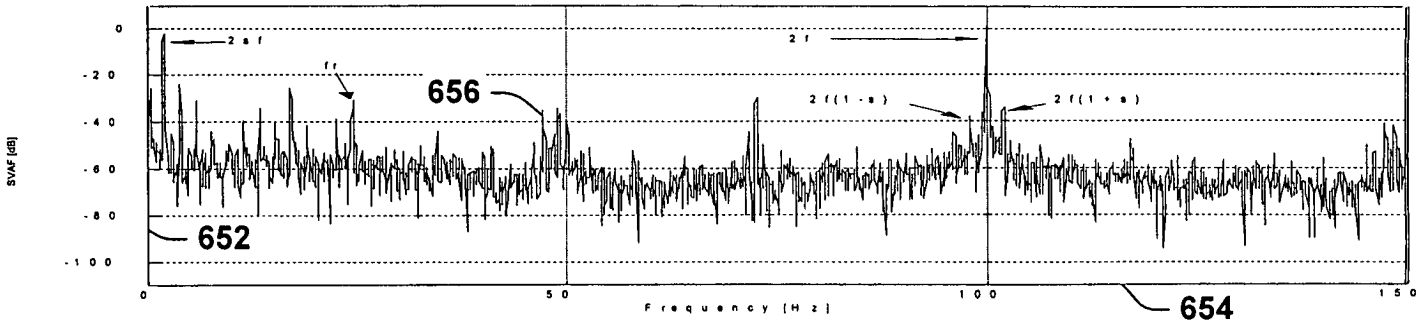
650
656
652
654
2 s f
fr
2 f
2 f(1 - s)
2 f(1 + s)
SVAF [dB]
Frequency [Hz]

FIG. 29

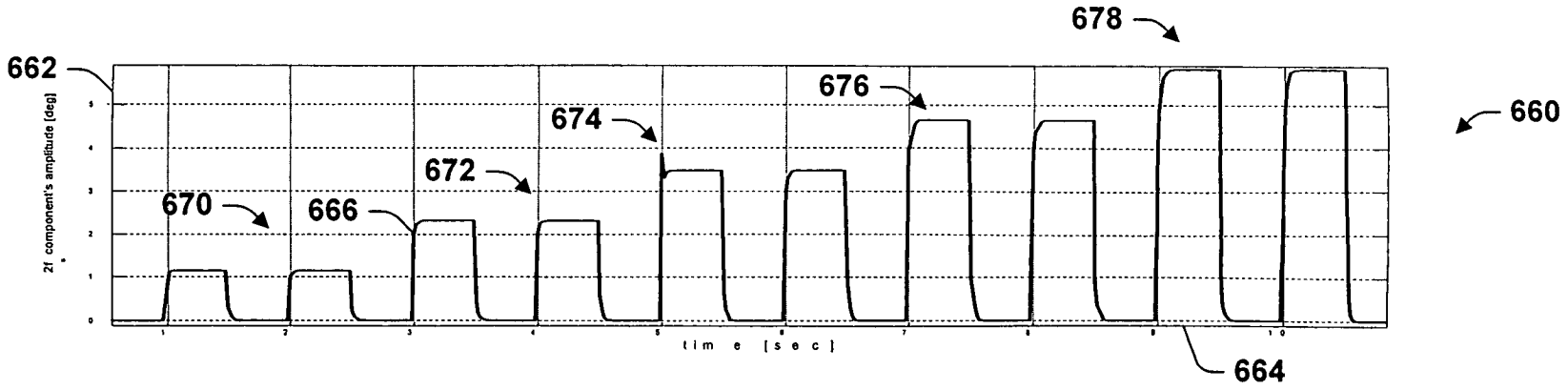
662
678
676
674
672
670
666
660
664
2t component's amplitude [deg]
time [sec]

FIG. 30

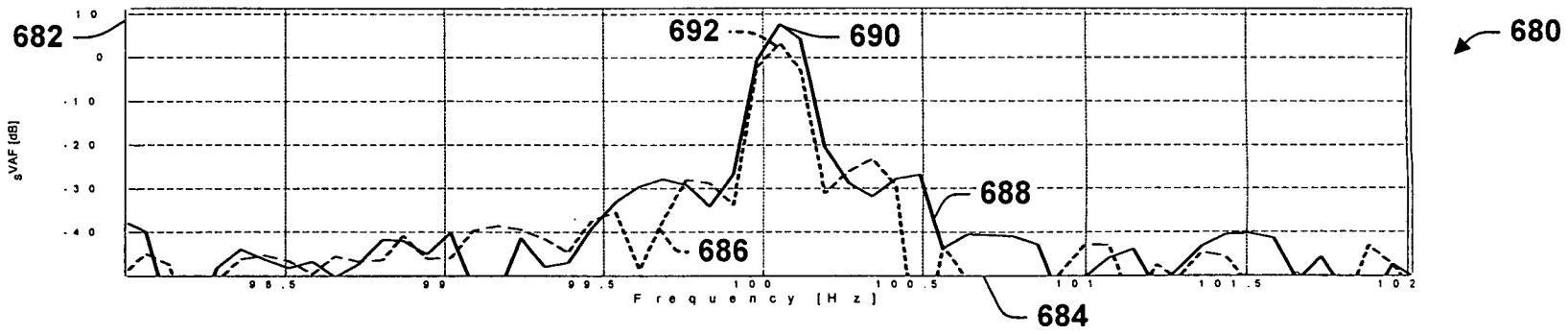
682
692
690
680
688
686
684
sVAF [dB]
Frequency [Hz]

FIG. 31

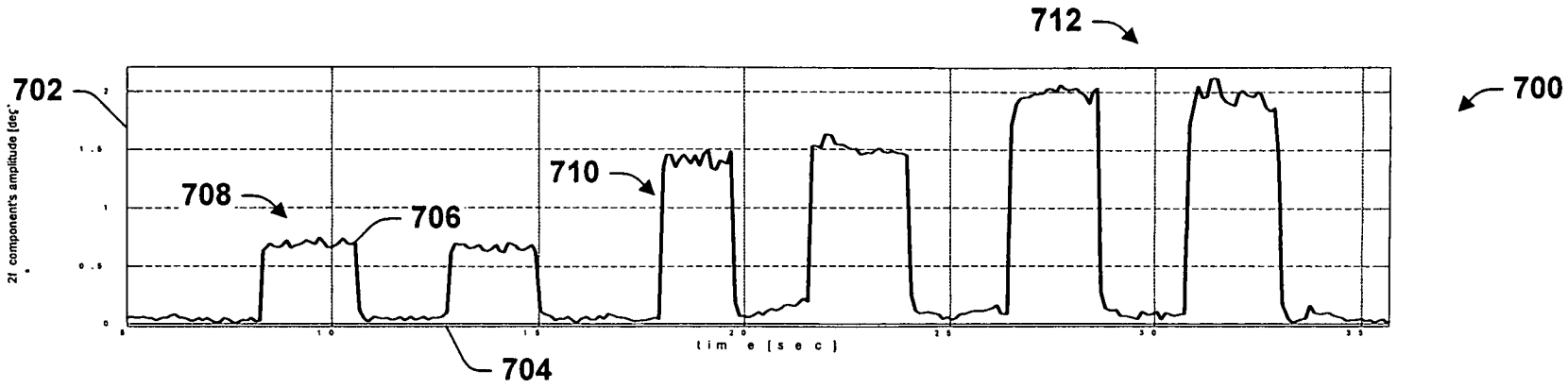

FIG. 32

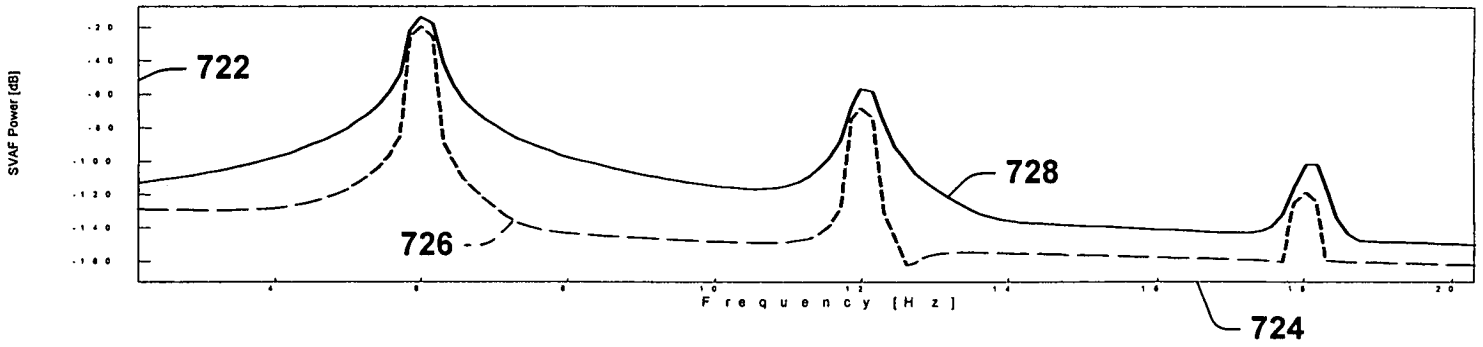

FIG. 33

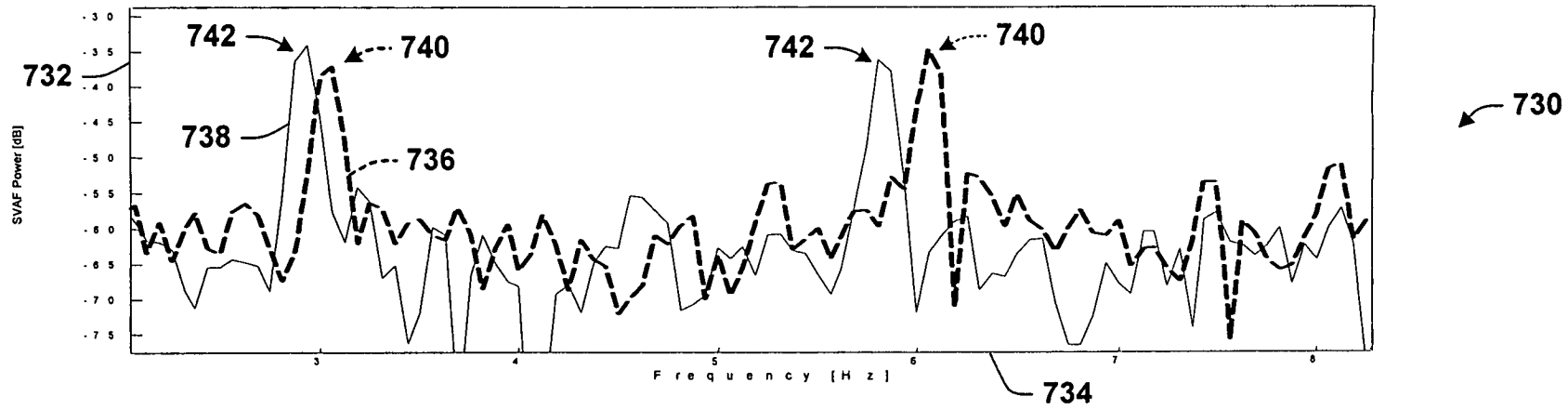

FIG. 34

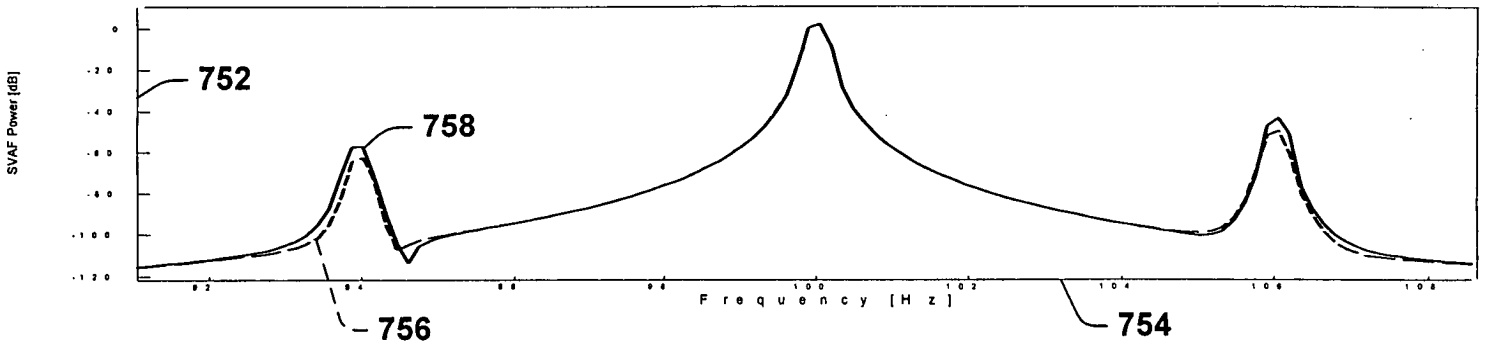

FIG. 35

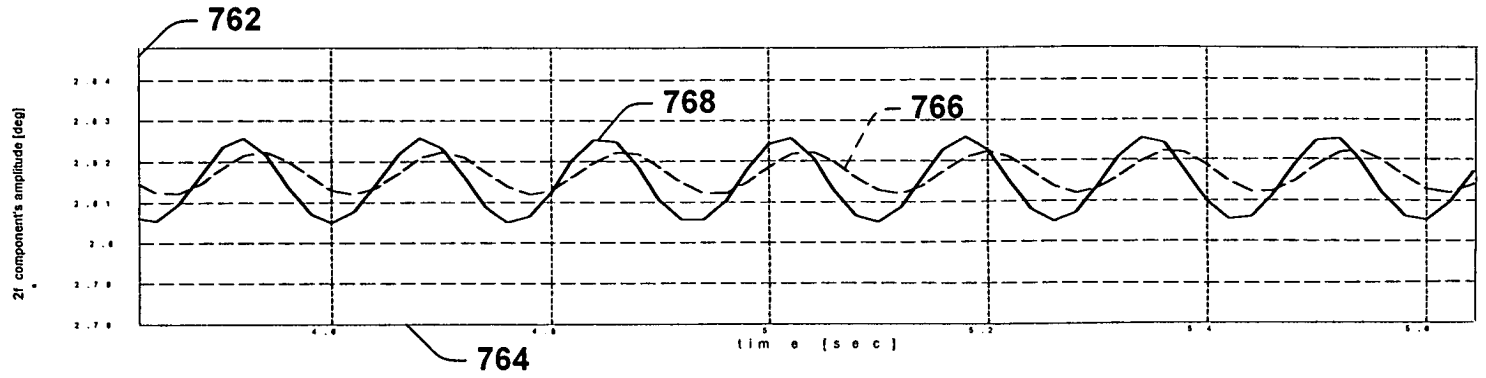

FIG. 36

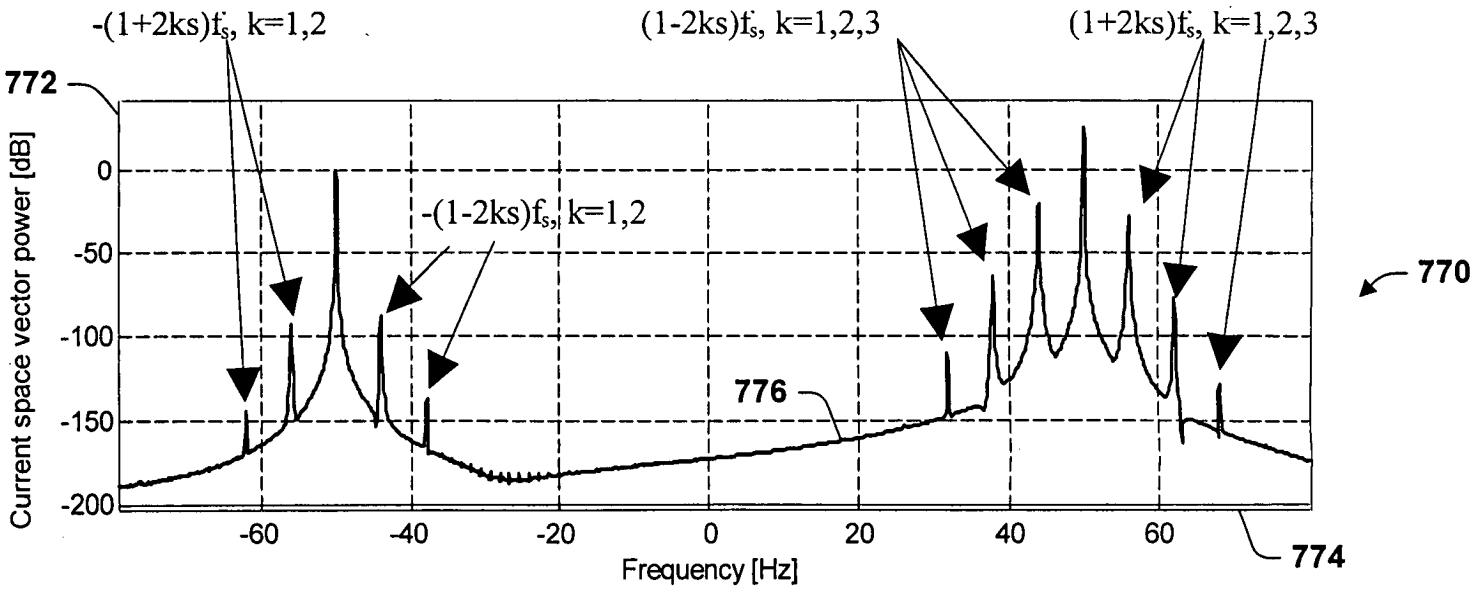
-(1+2ks)fs, k=1,2
(1-2ks)fs, k=1,2,3
(1+2ks)fs, k=1,2,3
772
-(1-2ks)fs, k=1,2
776
770
774
Current space vector power [dB]
Frequency [Hz]
0
-50
-100
-150
-200
-60
-40
-20
0
20
40
60

FIG. 37

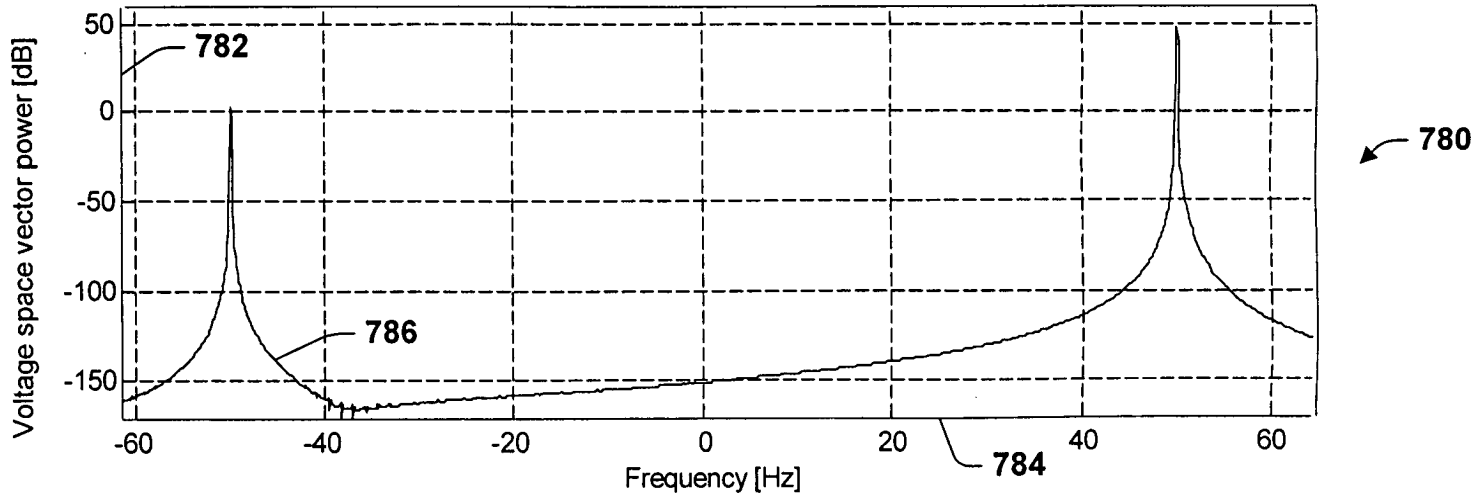
782
786
780
784
Voltage space vector power [dB]
Frequency [Hz]
50
0
-50
-100
-150
-60
-40
-20
0
20
40
60

FIG. 38

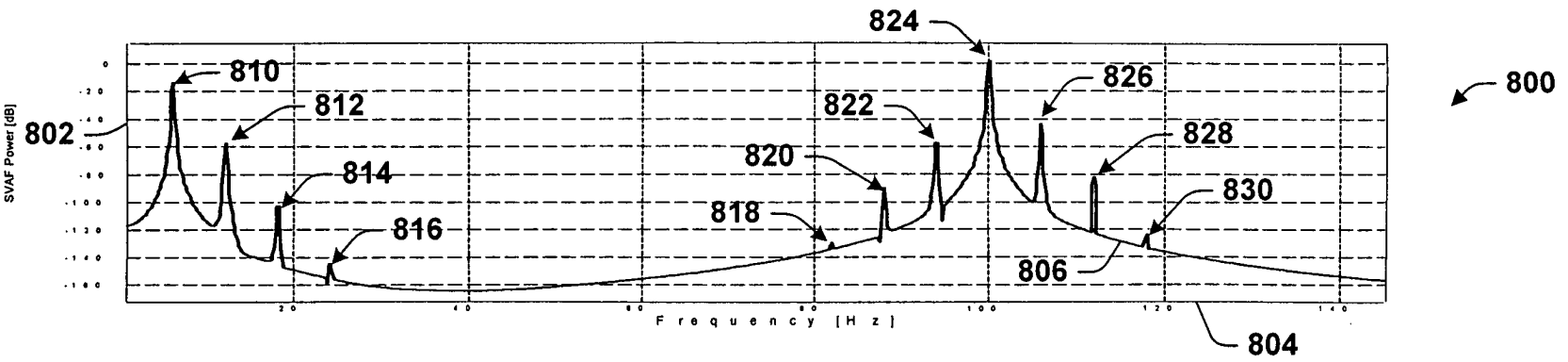
824
810
826
812
822
802
828
820
814
830
818
816
806
800
804
SVAF Power [dB]
Frequency [Hz]

FIG. 39

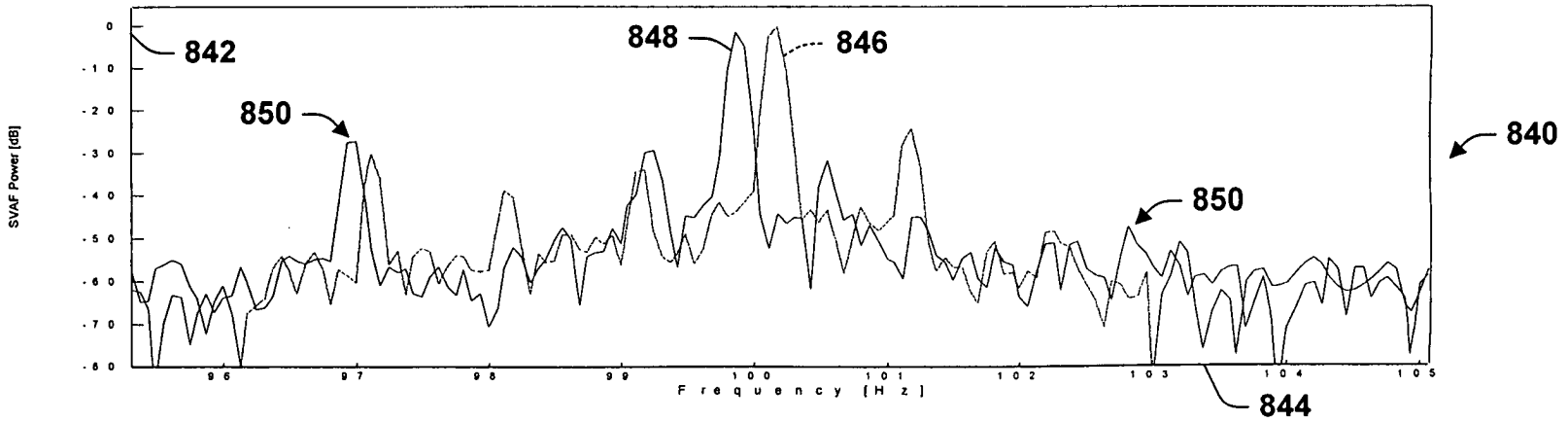
842
848
846
850
840
850
844
SVAF Power [dB]
Frequency [Hz]

FIG. 40

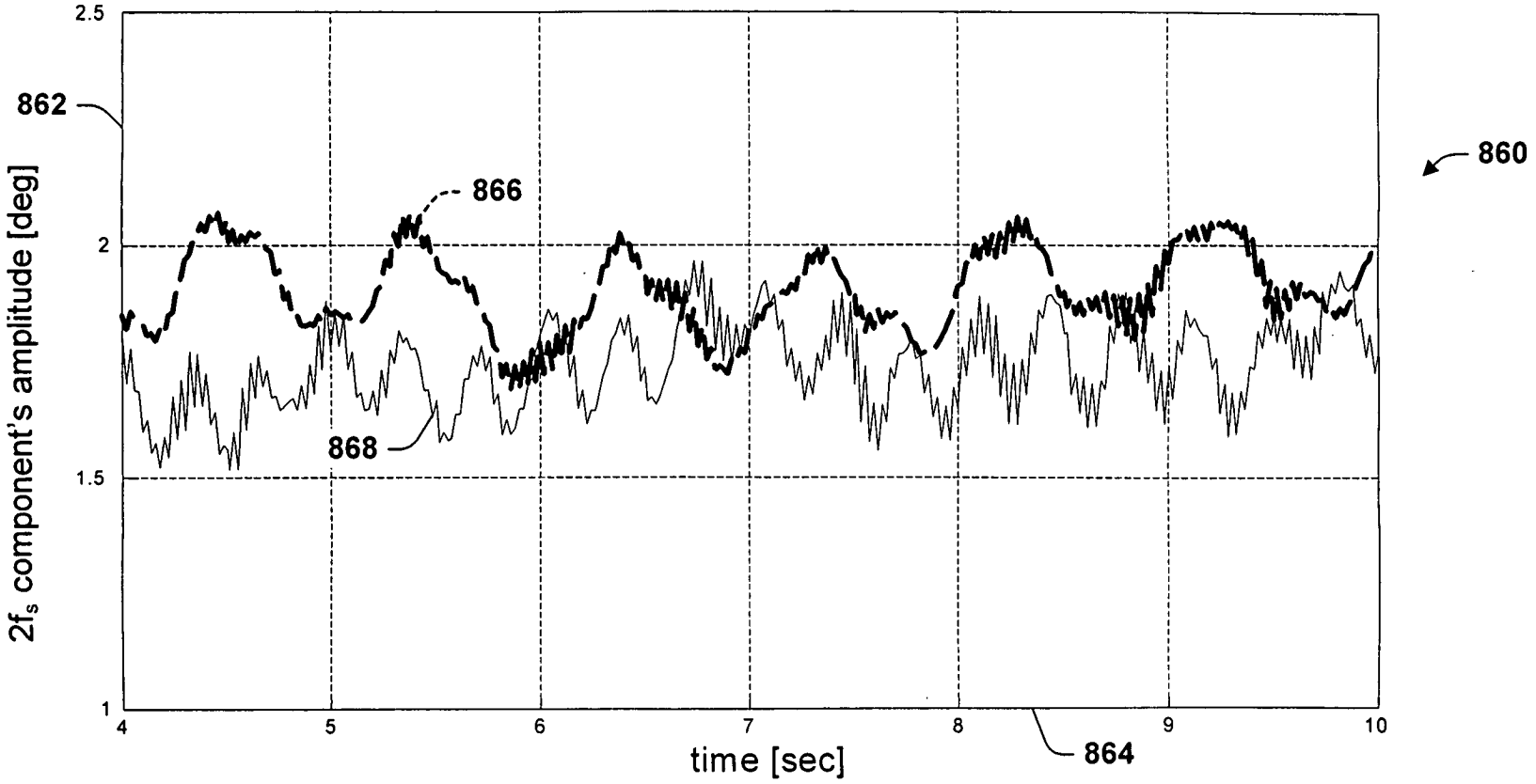
2.5
2
1.5
1
862
866
868
860
864
4
5
6
7
8
9
10
time [sec]
2f_s component's amplitude [deg]

FIG. 41

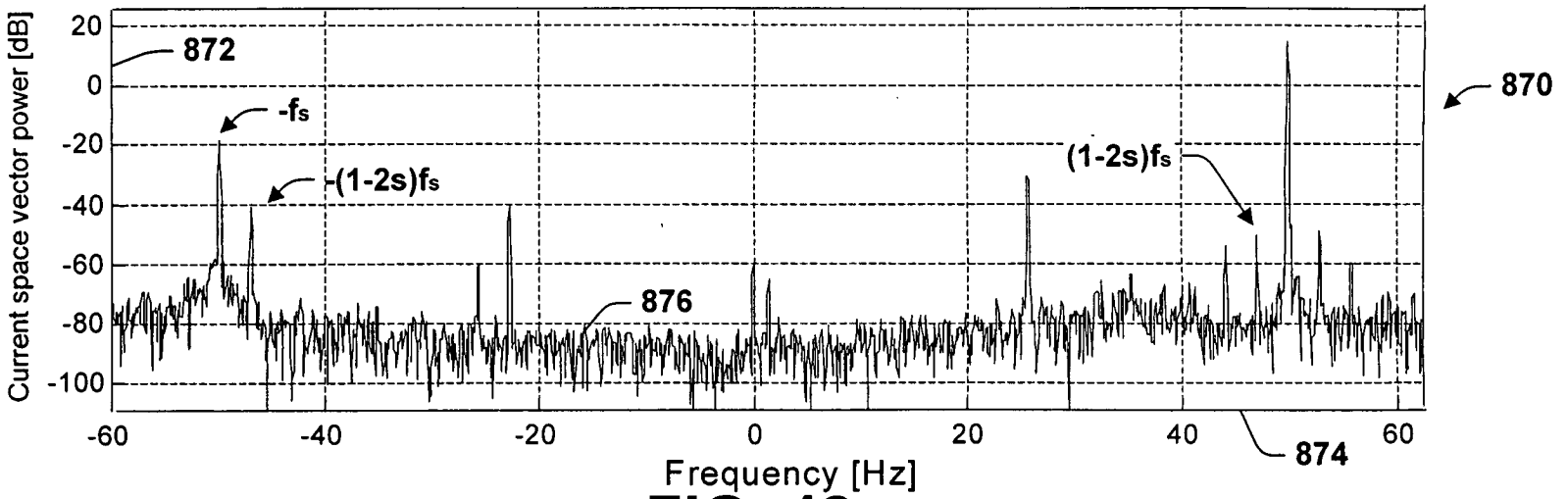
Current space vector power [dB]
20
0
-20
-40
-60
-80
-100
872
-fs
-(1-2s)fs
876
(1-2s)fs
870
874
-60
-40
-20
0
20
40
60
Frequency [Hz]

FIG. 42

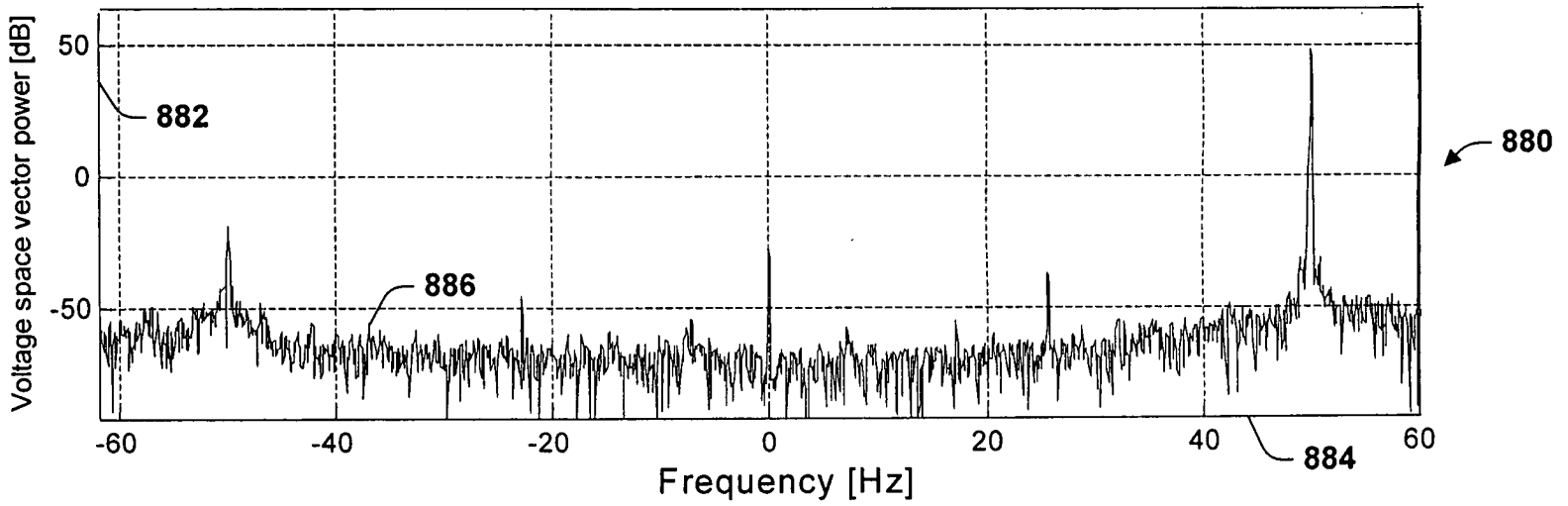
Voltage space vector power [dB]
50
0
-50
882
886
880
884
-60
-40
-20
0
20
40
60
Frequency [Hz]

FIG. 43

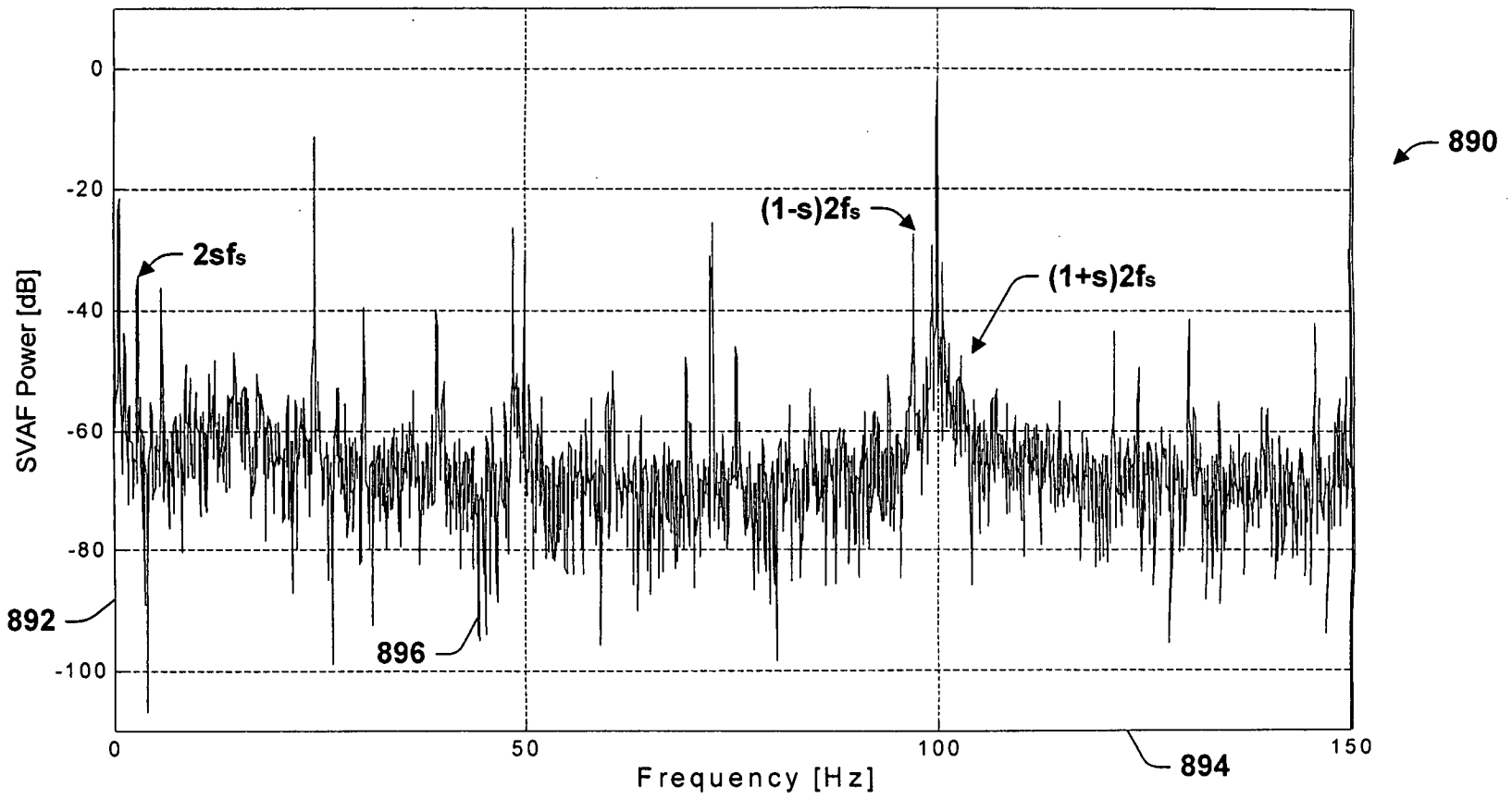

FIG. 44